THE POTASH SALTS.

Their production and application

TO

AGRICULTURE,

INDUSTRY

AND

HORTICULTURE,

BY

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PREFACE.

It affords me considerable pleasure to write an introduction to the present book for several reasons, and I hope that the subject matter contained therein will be widely read in this country by all interested in land cultivation.

It is singular that in the variety of manuals describing the details of almost every technical subject, no special work dealing with so important an industry as that of the utilisation of the natural potash deposits should have appeared in England. This is the more to be regretted as the advancement of knowledge as to the improvement of the fertility of soils in an agricultural area so limited, and yet so imperfectly developed as that of the British Islands, must be considered in the light of a national benefit. There are, undoubtedly, millions of acres now barren that owe their want of productiveness either to a natural absence of certain saline constituents in the soil, or to a depletion in this respect occasioned by long injudicious cultivation. And to diminished or retarded growth may be added an inferiority of quality in the yield that is capable of prevention, as shown in Dr. Groth's treatise, by a suitable dressing of potash manure salts. Another important point demonstrated in this volume is that, even where scientific farming has been conscientiously attempted, large sums of money have been expended on imperfect manures containing only a portion of the nutriment demanded by plants, and merely requiring the supplement of potash compounds

to render the whole value of the fertiliser available. In many cases superphosphate or Chili nitrate have been generously distributed with similar results to those noticed in animals or man when confined to an imperfect dietary, viz., that the larger part of the food given is unassimilated. Such failures from want of knowledge have frequently led to the abandonment of "artificials," and to the neglect of areas as not worth farming, which a judicious use of alkaline salts, at a small cost, would have transformed into fertile and profitable fields.

I well remember, at the meeting of the British Association in Bristol, how Sir William Crookes awakened the general public to the danger of the world's supply of wheat being diminished by progressive exhaustion of soils and the gradual advance of a nitrogen famine. Dr. Groth has shown the actual prevalence of potash starvation, and that even in Germany, where the salts he describes are mined in such quantities, they are not used in adequate proportion. From the examples he cites, attention to the needs of the soil for a complete manure has been more general, with conspicuously successful results, in Scotland, and the economy is clearly proved by the figures—the experiments having been carried out by leading agricultural authorities on a scale sufficiently large to be practical, and conducted with an accuracy and care which have left no doubt in the conclusions. It is gratifying to learn from this book, that besides the valuable observations at Rothamsted, and those made by various Agricultural Associations on the lines that have long been consistently advocated by chemists, a number of farmers and landed proprietors have carried out trials leading to concordant results as to the benefit of potash compounds even as adjuncts to farmyard manure. The lessons of the Rothamsted and other reports, although well-known in the scientific world, seem up to

the present, however, to have penetrated very little distance among the farming interest. The Fertilisers and Feeding Stuffs Act of 1893 is a very useful one, but the results of the working, as shown by the Board of Agriculture, clearly demonstrate that farmers have not taken full advantage of the facilities afforded therein of ascertaining the composition and purity of commercial fertilisers. It is to be hoped that County Councils will avail themselves generally, as they have in some localities, of their powers for educating cultivators in improved methods of tillage. A master agriculturist without scientific knowledge of his craft, such as can be gained at an Agricultural College, or in many technical classes, can hardly be considered an item in the prosperity of his country.

In Ireland the consumption of artificials is very low, especially with regard to potash, as seen by Dr. Groth's tables, in spite of the known avidity of potatoes for this substance. It is to be hoped that the satisfactory results which a few enterprising proprietors have obtained will give a stimulus to proper cultivation in preference to neglecting the land, and thus diminish complaints of low rents and of the country's impoverished condition.

The section of the work dealing with horticulture, particularly in reference to fruit-raising, gives information that will be novel, and is of great importance in view of the large areas devoted to fruit trees in Kent and in the West, and to berries in the North of England and in Scotland. Although it is known that flavour and quality are greatly affected by soil, it is to be feared that the care of the ground, where it is not left entirely untended, is limited to trenching and sparingly dosing with stable manure, with the result of deterioration of the sorts and decline of the yield.

In the Colonies, even virgin soil is impoverished by the removal of mineral constituents in the crops, and it should be the object to restore the loss by suitable applications, and to look on the expenditure as a kind of sinking fund for maintaining the fertility.

The ensuing descriptions of the geology of the potash districts, the nature of the salts and the methods of raising, are very complete, and cannot fail to be generally interesting, and although it is manifest that the industry has reached large proportions, it is evident that capital spent in this natural source of wealth will be advantageous to any country, and especially to our own agriculture. The numerous manufactures making use of the potash salts, especially in electrical developments, are also described, with very full statistics as to labour and production. A practical account of the machinery concerned closes a volume which appeals to a number of interests, and is accompanied by maps, sections and other drawings, many of which are published for the first time.

SAMUEL RIDEAL.

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23rd June, 1902.

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GENERAL REMARKS

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- Canada
- France
- Galicia
- India

GENERAL REMARKS.

The many-sided value of Potash in agriculture and various trades, with the important changes developed in the past few years in its production, manufacture and use, resulting at the present time in such an extraordinary advance, have led to the creation of an entirely new and important staple-industry, which in Germany actually competes in success with the industries of coal and iron. That country now, in fact, in relation to potash salts, controls the markets of the world, as it is solely from her resources that every country supplies its needs in products so essential to modern practice in farming and manufactures.

The present status, as well as the future prosperity of this industry, is based upon the following existing conditions:—

1. The wide use of fertilizers, in which potassium-salts are indispensable constituents;
2. The practical limitation of potassium-salt deposits to German territory;
3. The great extent and richness of these exclusive sources.

In view of these considerations it is easily appreciated how the utilization of this natural wealth has led to advances in the methods of agriculture, has assisted older technical industries and initiated new ones, and in this way compels attention on the grounds of scientific interest, of public benefit, and of profitable investment.

The metal potassium possesses unusual interest not only from its own properties but from its having been the first link in the chain of discovery by which Sir Humphrey Davy opened out an obscure region of knowledge and contributed essentially to the foundation of modern chemistry. From its extraordinary affinity for oxygen it is difficult to preserve in the metallic state. It is the metallic nucleus of *Potash*, a name derived from its having been originally obtained in an impure state by evaporating in iron pots a lye from the ashes of wood. With the progressive destruction of the forests, however, this source contracted, and raw wood-ashes and the potash produced therefrom now play an unimportant part in the alkali market, although Canada still produces a considerable quantity of potash from wood, a commodity having special advantages likely to keep it always in demand

for soap-making, and of which a large quantity is employed in this manufacture, notably for the use of the British Navy. The following table illustrates this branch of production :—

Canadian Exports of Potash
stated in barrels, during five years.

Year.	1894.	1895.	1896.	1897.	1898.
Potash	1,936	1,904	1,964	1,404	1,080
Pearlash	224	415	295	176	243
Total	2,160	2,319	2,259	1,580	1,323

The falling off in the exports was in great part due to adulteration and to other trade delinquencies. Potash is very much reduced in value by any admixture of common salt; so much is this the case that potash made from vegetables or trees grown where the water is saline is decidedly inferior in quality.

In **France** a small quantity—about 2,000 tons—of commercial potassium chloride, or " muriate of potash " is annually produced by the evaporation of sea-water.

In **India** about 20,000 tons of nitrate of potash is obtained annually, and about 1,200 tons come from the mines at Kalusz, in **Galicia**, the only potash mine outside of Germany.

Felspar and some other minerals, containing more or less potash, may be classed as commercially inapplicable for its production, since it is not found possible to separate from them, in a simple and cheap way, readily soluble combinations of potash, while even when finely powdered they are practically inert as manures on account of their insolubility.

Potash has been extracted from beet-root molasses, from the ashes of sea-weeds, and also from wool-fat or " suint."

These sources, however, are almost insignificant when compared with the present demand, which exceeds 3,000,000 tons per annum, now for the most part obtained from the great deposits of potash-salts occurring naturally at various places in Germany, and known in general as Stassfurt-Potash-Salts.

DISCOVERY
of the
NATURAL
POTASH
SALTS.

DISCOVERY OF THE NATURAL POTASH-SALTS.

Centuries ago, "sool" or brine-springs were already known to exist in the vicinity of the small town of Stassfurt in Prussia, but they were first officially recognised in the 13th Century, the "Abesse Anna von Schladen" building the first sool-well in 1452. The salt works, producing the salt from these sool-springs, came afterwards into the possession of the Duke of Anhalt, who in the year 1796 sold them to the Prussian Government for 250,000 marks, or about £12,500.

Special interest is attached to the statement made by Georgius Agricola in his book "De ortu et causis subterraneorum," published in 1612 at Wittenberg, referring to the "natura fossilium," which may be taken as the first report upon potash-mining.

Referring to the sool-springs, Agricola speaks as follows: "Quinetiam sal Stasphurdi in Saxonibus fadi posset. Nam et aestivo tempore campi sale aspersi videntur esse et semper effluunt salsae." (In Stassfurt, Saxony, the salt can now be obtained by cutting with chisel, as not only are the fields seen in the warm summertime to be sown with salt, but the salt springs run continually.)

The opinion expressed by Agricola: "that the salt springs must have their origin in layers of salt," remained unheeded for two centuries or until 1838, when the treatise above-named was rediscovered, and its contents received attention.

About this period the consumption of common salt for cooking purposes had increased to such an extent in Prussia that the supply from the salt springs had become entirely insufficient. The mining officials were called upon seriously to consider if saline beds could not be reached by means of deep borings. Two reports were subsequently obtained from C. Reinworth, in Dresden, dated respectively the 3rd June and the 24th August, 1838. Dr. Ober Bergrath Karsten (Mining Councillor) came to the conclusion, as stated in his report of 11th October, 1838, "that the sool-springs, which had existed for centuries, and had produced every year about 2,500 tons of common salt, with a percentage of 17·75 pure salt, could not obtain their salt but from rich saline beds, and that by means of deep borings in the neighbourhood of these sool-springs, the saline beds would probably be reached."

The presence of potash-salts was not at that time under consideration.

By order of the Prussian Government the first boring was commenced on the 23rd April, 1839, in the vicinity of Erfurt, in the Thuringian basin. The saline bed was reached in 1843, at a depth of 768 feet, a discovery which attracted considerable notice, but upon examination of the salt it was found to be composed of a mixture of magnesium and potassium compounds. Though the result was looked upon as unfavourable, the boring was continued, entirely through a saline bed of 975 feet, having thus reached a depth of 1,743 feet, when it was discontinued, although the base of the deposit had not been reached.

Boring was recommenced in the neighbourhood of the springs and salt was found from the beginning, the percentage of pure salt increasing with the depth, as follows :—

At 62 feet ... 10·1 per cent.			At 592 feet ... 17·7 per cent.	
,, 259 ,, ... 11·22	,,		,, 701 ,, ... 18·87	,,
,, 300 ,, ... 12·5	,,		,, 729 ,, ... 19·34	,,
,, 469 ,, ... 13·1	,,		,, 741 ,, ... 20·10	,,
,, 475 ,, ... 14·4	,,		,, 749 ,, ... 21·93	,,
,, 493 ,, ... 15·8	,,		,, 777 ,, ... 27·40	,,
,, 553 ,, ... 16·8	,,			

The temperature in the bore-hole was as follows :—

At 50 feet ... 11° centigrade			At 639 feet ... 14·2° centigrade	
,, 430 ,, ... 12°	,,		,, 870 ,, ... 15·4°	,,
,, 493 ,, .. 13·2°	,,		,, 906 ,, ... 16·2°	,,

The existence of compact layers of salt under Stassfurt having thus been proved, it was nevertheless found that it was by no means a pure sodium chloride salt, but a double compound of chloride of sodium and magnesium, the analyses having given :—

16 per cent. chloride of sodium.

13 per cent. chloride of magnesium.

instead of 27 per cent. chloride of sodium, which the brine was expected to yield.

Later analyses gave :—

5·61 per cent. chloride of sodium.

19·43 per cent. chloride of magnesium.

2·24 per cent. chloride of potassium.

4·01 per cent. sulphate of magnesium.

This appeared strange, as the samples brought up, particularly from the bottom of the bore-hole, contained pieces of almost pure rock-salt, only slightly mixed with anhydrite.

The great question arose, therefore, if it would be advisable to risk the great expense connected with the sinking of a shaft for the purpose of mining this "by no means pure salt."

Von Cotta wrote as late as 1854, in "Deutschlands Boden," I., page 182:—"Unfortunately the Stassfurt rock-salt, judging from the samples taken from the borings, is mixed very much with bitter salts, and contains, besides, large quantities of boracite."

Further investigations having been demanded and reports thereon delivered by Dr. Karsten and Professor Marchand, it was finally decided to commence the mining of rock-salt.

On the 14th of December, 1851, the sinking of the first shaft was commenced in the vicinity of the bore-hole, with the object of serving as a standard for the future, the shaft being given the name of "Von der Heydt," in honour of the Minister of Finance.

The sinking of a second shaft, christened "Manteuffel," commenced on the 31st December, 1852.

Both were sunk without any difficulties, and were connected at various depths by means of cross-levels.

The actual working commenced in 1857.

The section of these two shafts is shown in figure 11, page 52.

Further explorations were now commenced. The Government of the Duchy of Anhalt commenced borings in 1855 at Leopoldshall, in the immediate neighbourhood of Stassfurt, and within its own territory, with perfect success. The saline beds were reached at a depth of 435 feet, and soon a new salt was discovered in great quantity, giving a new impulse to the trade in the district. This salt was "Kainite," a mixture of sulphate of potash, chloride of magnesium and common salt. It is the cheapest form of the crude potash-salts, and is used principally as manure, for which purpose it can be employed in the crude state in which it is raised from the mines; it also serves for the manufacture of pure sulphate of potash, the applications of which are numerous.

The success of the borings thus commenced by the two Governments, the increasing consumption of the products, and the highly satisfactory and remunerative character of the new industry, soon brought private enterprise into the field, which commenced by developing the mines at Loederburg and Westeregeln, to be subsequently taken over by the Neu Stassfurt and Douglashall works. Explorations were soon extended beyond the immediate neighbourhood of Stassfurt into the Province of Hanover, in the Duchy of Brunswick, and near the

Thuringian Forest, with results more or less favourable. To the successful list already mentioned new mines, were thus, from time to time, added notably "Ludwig II.," "Schmidtmanshall," and the "German Solvay" works, while beyond the limits of the Stassfurt district were the "Vienenburg" mines at Goslar, the "Anderbeck" mines, near Halberstadt; those of "Luebtheen," in Mecklenburg; and of "Thiede," in Brunswick.

These were the first undertakings which established the credit of the German Potash salts industry, and originated the era of feverish activity that prevailed for some years in this field.

In 1889 further prospecting was commenced between Goslar and Hildesheim, by the "Goslar Tiefbohrgesellschaft," and in Allerthal, north of Helmstedt, by a company afterwards formed into the "Gewerkschaft Burback."

The success attending these undertakings aroused widespread interest, and, favoured by an active mining market as well as outside capital, many new companies were formed, whose field of operations extended over a great part of north and middle Germany, more especially the Province of Hanover and the Thuringian States. Most of these companies failed to locate workable deposits and went into liquidation; of the survivors, some persevered in boring, whilst others are now sinking shafts and preparing to work the deposits which the borings had shown to exist.

Fears which prevailed at one time that the new discoveries would bring about an over-production and a subsequent decline in prices and possibly ruin of the older works, have proved groundless.

The object of earlier enterprise being merely to obtain rock salt, other products, such as potash and magnesium salts, found to be deposited in the upper layers, had to be cleared away in order to reach the rock salt, and from the original idea that they were useless, were called in Germany "Abraum Salz," a name which is still retained. Subsequently, however, on the discovery of their real value they became the origin of a new flourishing and staple industry. Their utilization was the outcome of much labour and research, and it was through the efforts of A. Frank that the first large works were established.

COMMERCIAL
INDUSTRIAL
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COMMERCIAL AND INDUSTRIAL DEVELOPMENT OF THE POTASH MINES.

In the first part of the present decade, influenced by the feverish excitement that prevailed at this time, the expensive operation of sinking shafts was often undertaken with only the scanty knowledge regarding the deposits that could be gained from a single drill hole. It was soon learned that this was a very expensive manner of procedure, as the results actually obtained did not correspond with those shown in the boring. This common experience also brought about a great decline in the market prices of the stocks of these companies.

Boring is mostly by the diamond core drill, the steel bit being used only in sinking through the loose surface material. When salt beds are reached a concentrated solution of magnesium chloride is used, instead of water, to wash away the fine material broken up by the drill.

The boring companies issue usually 1,000 shares, at a par value of 100 to 1,000 marks (£5 to £50), to defray the costs of mining rights and drilling. These shares, being subjected to violent fluctuations, have been the favourite objects of speculators. More than 150 companies of this character have been formed since 1890. Many of them drilled several holes, while others were liquidated without accomplishing anything. When it is stated that only a few of this number have attained valuable results, one can gain an idea of the enormous sums of money that have been expended in such enterprises. Nevertheless, it must not be forgotten that it is only by these borings, although attended by so great expense, that the knowledge and whereabouts of workable deposits of potash-salts have been obtained, and their indisputably great value is proved by the high price which is always obtainable in the market for the right of mining such potash-salt deposits.

The boring companies obtained good prices as well as favourable terms in various respects. As much as 150 marks (£7 10s.) per metre was paid for putting down a bore-hole, the actual cost of which would scarcely amount to 50 marks (£2 10s.). The depth of the holes varies from 600 to 4,200 feet (Salzdetfurth), and the boring companies generally guarantee a core at least 80 per cent. of the entire drill depth. The total amount of drilling may be placed at 500,000 feet.

Shaft-sinking offers no special difficulties so long as continued in the firm sandstone. A simple lining of masonry suffices, the material for which is often taken from the surrounding fields. After the rock-salt is reached, a cross-cut is run to the salt deposit. Very frequently water is encountered, and then tubing must be used. The presence of quicksand fissures, or diluvial sand, necessitates the adoption of freezing or other particular methods suited to the case, but so far the German engineers have successfully met all difficulties.

An instance of remarkable perseverance, under adverse conditions, is that of the Mecklenburgische Kalisalzwerke, Jessenitz (Fig. 7), near Luebtheen, which has just succeeded in reaching the rock-salt after 15 years of continuous labour and great expense.

The cost of shaft sinking varies greatly and cannot be previously estimated, as it depends not only upon the depth but also on other circumstances, particularly the difficulties that may ensue from water. Generally, the expense runs from 800,000 to 2,000,000 marks, equal to £40,000 to £100,000, or somewhat more per shaft.

The shafts have a circular cross section, with a diameter of about five metres and a half.

The various enterprises may be grouped under three heads, according to their stage of progress :—

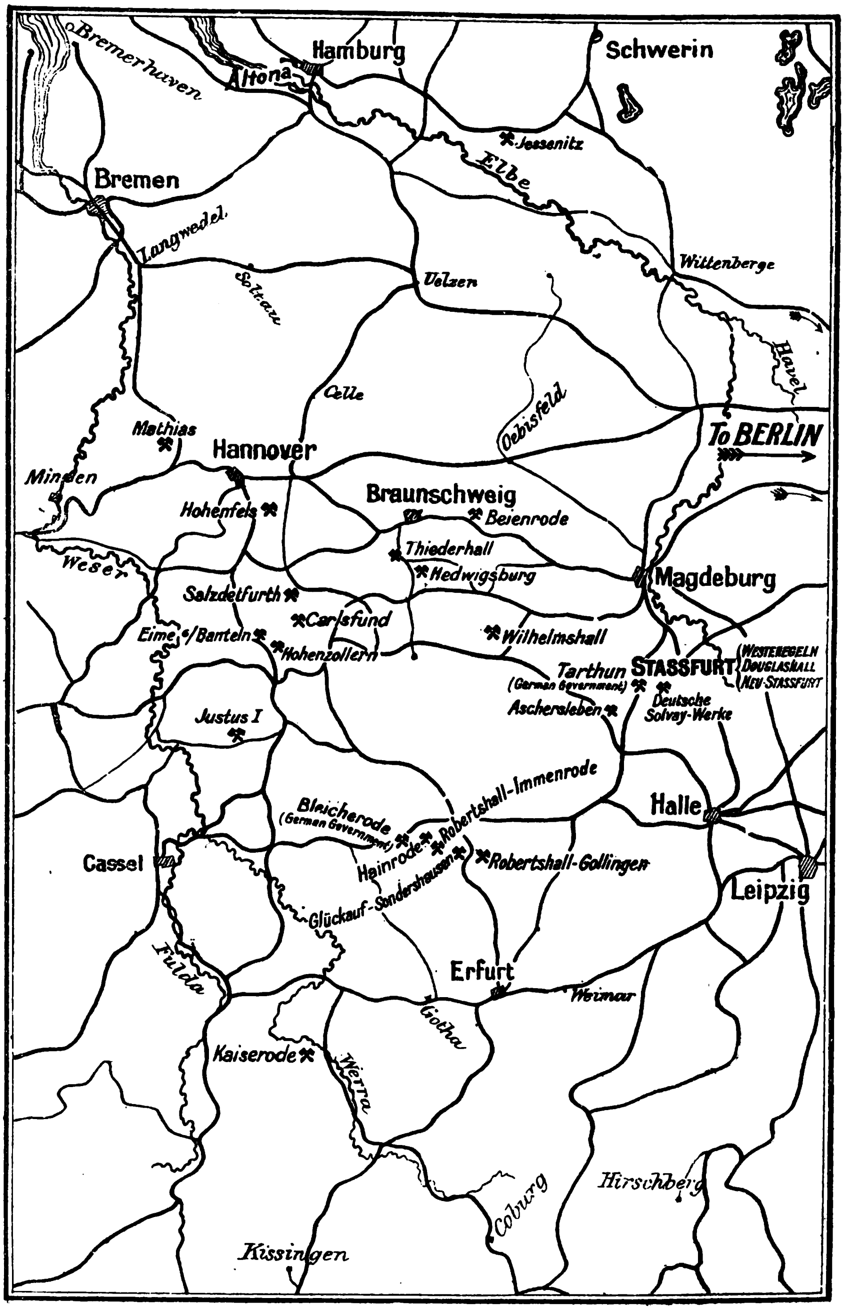
(1) Productive mines;
(2) Mines under development;
(3) Companies engaged in boring.

(1) Productive Mines.

Since the years 1851 and 1852, in which the Prussian Government sank the shafts, "Von der Heydt" and "Manteuffel," near Stassfurt, a number of mining companies have reached the productive stage. These, as well as the chemical works connected with them, in order to protect their interests, united and formed a syndicate, with which all the new producers from time to time have become connected.

One kilo = 2.2 lbs. A centner is 50 kilos = 110 lbs., or nearly a cwt. One double centner = 100 kilos = 220 lbs. A metric ton is 1,000 kilos = 2,204.6 lbs., or a little less than an English ton. A metre is 39.37 inches. A mark = One shilling

Fig. 1. Plan of the Potash District.



The following table will show :—

Names of working mines, their number of shafts, time of sinking, and commencement of actual working.

No.	No. of Shafts.	Name of Mine.	Date of Commencement of Sinking.	Date of Commencement of Working.
1	7	Prussian Government ("Fiscus")	1851	1857
2	6	Anhalt " "	1858	1862
3	4	Westeregeln	1871	1874
4	4	Neustassfurt	1873	1877
5	5	Aschersleben	1880	1883
6	1	Ludwig II.	1873	1884
7	2	Hercynia	1884	1886
8	2	Solvaywerke	1884	1889
9	1	Thiederhall	1885	1891
10	1	Wilhelmshall	1886	1893
11	1	Glückauf-Sondershausen	1893	1895
12	1	Hedwigsburg	1895	1897
13	1	Burbach	1897	1898
14	1	Carlsfund	1896	1899
15	1	Beienrode	1894	1899
16	–	Asse	1899	1901
17	1	Salzdetfurth	1896	1899
18	1	Jessenitz	1886	Not yet
19	1	Hohenzollern	1897	1899
20	1	Justus I.	1896	1899

On the previous page (Fig. 1), we give a map showing the position of the potash mines.

With the exception of the Glückauf-Sondershausen, which lies upon the south side of the Harz, all the other mines are situated in the northern part of the Harz district. The first six mentioned and the Solvay works are within the Stassfurt basin, the Hercynia is in the vicinity of Goslar, while the Wilhelmshall is not far from Halberstedt, in a continuation of the Stassfurt basin westward, that includes also the mines of Thiederhall and Hedwigsburg, in Brunswick. The Burbach mines are on the northern border of the Stassfurt basin, not far from Helmstedt.

The relative importance of the different mines may be seen from the table on page 69, giving the contribution of each mine to the "Potash Syndicate."

The old Stassfurt mines have been supplied with modern machinery, whilst those of recent years can compare favourably in this respect with any other class of mines. In fact, they represent the highest development of mining technique as regards machinery, ventilation, hygiene and costs of production.

Most of the mines have more than one shaft. Electricity is used in drilling, lighting, and transport.

The methods of working the mines vary according to the physical qualities of the minerals and the dip of the beds ; usually the panel or stoping system is adopted. Gobbing is practised in all mines, the material for which, rock-salt, is broken in mills built specially for this purpose.

Drainage is unnecessary, but when water appears it may cause a closing down of the mine, as has lately been the case with Leopoldshall.

In addition to the chemical works, which are directly connected with the mines, there are extensive mills for breaking and pulverising the minerals used for agricultural purposes.

Wages are high, the workmen well fed and contented.

As to the *financial position* of the various mines, it has been difficult, in some cases impossible, to obtain full information ; the following official statements may, however, give a general idea of the profitable nature of potash mining :—

ASCHERSLEBEN, in the Province of Saxony.

Share Capital	12,000,000 marks =	£600,000	
Loan ,, @ 4% ...	3,600,000 ,,	180,000	£780,000
Gross Profits for 1896 ...	2,221,000 marks =	£111,050	
,, ,, 1897 ...	2,896,373 ,,	144,819	
,, 1898 ...	3,108,718 ,,	155,436	
,, ,, 1899 ...	not obtained.	—	
,, ,, 1900 ...	3,871,082 ,,	193,554	

The balance sheet for 1900 shows the following enormous sums set off for depreciation :—

Gross Profits		M 3,871,082.54	
Interest on Loan...	M 148,301.65		
General Expenses	314,331.69		
Depreciation	1,955,101.78		
		2,417,935.12	
	Net Profit	M 1,453,147,42	= £72,658
The General Reserve	787,687 marks		
,, Special ,, ...	724,530 ,,		
		1,512,217 marks	= £75,615

A Dividend has been paid of 7 per cent. in 1896
,, ,, ,, 10 ,, 1897
,, ,, ,, 10 ,, 1898
,, ,, ,, 10 ,, 1899
,, ,, ,, 16 ,, 1900

Fig. 2. Main View of the Potash Mines, Aschersleben.

THE PRUSSIAN GOVERNMENT MINES.

The annual *net* profit (from 1st April to 31st March) has been as follows:—

In 1894–5	1,397,843	marks =	£69,892
„ 1895–6	2,066,504	„	103,325
„ 1896–7	2,235,994	„	111,799
„ 1897–8	2,128,442	„	106,422
„ 1898–9	2,340,286	„	117,014
„ 1899–1900	3,103,237	„	155,162

THE SOLVAY WORKS in Anhalt.

Share Capital	10,000,000	marks =	£500,000
Net Profit, 1895	3,925,571	„	196,278
„ 1896	5,255,615	„	262,780
„ 1897	5,379,904	„	268,995
„ 1898	6,417,377	„	320,868

WESTEREGELN, in the Province of Saxony.

Capital: 8,400 Ordinary Shares @ 1,000 marks		=	8,400,000 M. =	£420,000
4,000 Preference „ 1,000 „			4,000,000 „	200,000
			12,400,000 M. =	£620,000
1898—Gross Profit...		...	M. 3,516,535.58 =	£175,827
General Expenses ...	M. 231,799.91			
Repairs	131,020.23			
Depreciation ...	991,908.00			
			1,354,728.14 =	£67,736
Net Profit ...			M. 2,161,807.44 =	£108,091
Dividend: 15%				
1899—Gross Profit...		...	M. 3,814,348.88 =	£190,717
General Expenses ...	M. 276,567.17			
Repairs	56,881.29			
Depreciation ..	1,100,494.76			
			1,433,942.22 =	£71,697
Net Profit ...			M. 2,380,405.66 =	£119,020
Dividend: 17%				
1900 Gross Profit...			M. 4,349,911.91 =	£217,495
General Expenses ...	M. 313,768.35			
Repairs	65,688.90			
Depreciation ...	1,505,215.47			
			1,884,672.22 =	£94,233
Net Profit ...			M. 2,465,239.22 =	£123,262
Dividend: 17%				
1901—Gross Profit			M. 3,938,353 =	£196,918
Expenses, &c.			1,392,952 =	£69,642
Net Profit ...			M. 2,545,401 =	£127,276
Dividend: 17%				

In reference to the future profits to be earned by the various potash mines, it may be of interest to mention an article upon this subject, which appeared in *Industrie*, No. 164, for 1901 (the trade paper for potash mining), a translation of which reads as follows :—

"The average value of a year's output of potash-salts is well known to professional men, and if applied to the next year's output, as regulated and fixed by the Potash Syndicate, the net profit obtainable by each mine will, in all probability, be, during 1902, as follows :—

1.	Prussian Government	Mk.3,278,238	=	£163,912
2.	Anhalt ,, ...	2,887,065	=	144,353
3.	Westeregeln...	2,504,951	=	125,247
4.	Neustassfurt	2,504,951	=	125,247
5.	Aschersleben	2,504,951	=	125,247
6.	Hercynia	2,504,951	=	125,247
7.	Solvayworks	2,504,951	=	125,247
8.	Wilhelmshall	1,937,053	=	96,852
9.	Ludwig II.	1,565,609	=	78,280
10.	Glückauf	1,473,275	=	73,663
11.	Salzdetfurth	1,368,600	=	68,430
12.	Hedwigsburg	1,294,298	=	64,714
13.	Carlsfund	1,255,892	=	62,794
14.	Asse	1,255,892	=	62,794
15.	Burbach	1,236,434	=	61,821
16.	Beienrode	1,057,350	=	52,867
17.	Thiederhall	864,033	=	43,201
	Total	Mk.31,998,494	=	£1,599,916

"Consequently, one year's profit from the working of the potash mines will amount to nearly 32 million marks, or about £1,600,000.

"The actual sum produced will, of course, depend upon the more or less favourable conditions under which the respective mines will work during the year."

Fig. 4. Shaft 2 of the Potash Mines, Hercynia, Wöltingerode.

Fig 5. Shaft 1 of the Potash Mines, Hercynia at Vienenburg.

(2) **Mines under Development.**

These occupy a middle position between the first and third group, and comprise those in which the borings were sufficiently favourable to warrant further advance.

Shafts are now being sunk in several of these mines, whilst others, some of very great importance, are waiting for more favourable financial opportunities in order to get the capital required.

The companies which are now sinking shafts are :—

Mathias, situated near Wunstorf, in the Province of Hanover. One borehole has been drilled, and a potash bed of 21 feet thickness was found at a depth of 510 feet. During the sinking of the shaft difficulties from water were encountered, but have been overcome, and the shaft is approaching completion, about 2½ million marks (£125,000) having already been spent on the construction.

Eime, situated in the Province of Hanover. The potash beds have been located by two borings, viz. :—

Borehole i. at 885 metres, depth 12.64 metres, thick potash bed.
„ ii. „ 274 „ „ 10.0 „ „ „
„ iii. „ 751 „ „ 28.9 „ „ „

The shaft at the present depth of 270 metres (810 feet), has reached the rock salt bed. The analyses of the salt by Geheimerath Professor Dr. Kraut gave 99.6 per cent. sodium chloride, and in the second borehole, situated at a distance of 240 feet from the first one, the analyses of the salt gave 99 to 99.8 per cent. sodium chloride, thus showing a degree of purity rarely to be found elsewhere. The expenditure has been about 2 million marks (£100,000), and the shaft is still being sunk until the potash beds are reached. This company was amalgamated in 1899 with the neighbouring mine :—

New-Hohenzollern, which also had located the potash beds in
Borehole i. at 688 metres, depth 11.9 metres, thick potash bed.
„ ii. 679 „ „ 11.36 „ „ „

Wallmont-Benthe, in the Province of Hanover, has made five borings, in three of which potash has been located, viz. :—

In borehole III. at 1,695, 1867.5 feet depths, and in thicknesses of respectively 27 and 45 feet.

In borehole IV. at 1,017, 1,398, 1,426, 1,488 and 2,520 feet, the thickness of the beds being respectively 19.5, 22.5, 10.5. 12 and 66 feet.

In borehole V. at 1,395, 1,854, 2,043 and 2,613 feet, in thicknesses of respectively 3.3, 30 and 60 feet.

Siegfried I., in the Province of Hanover, potash salts have been found in

Borehole	I.,	at 2,291.5 feet,	in thickness	of	33	feet.
„	II.,	„ 2,149.5	„	„	18	„
„	III.,	„ 963.9	„	„	13.5	„
„	IV.,	„ 979.5	„	„	2.7	„
„	V.,	„ 2,280.0	„	„	16.8	„
„	V.,	„ 2,285.5	„	„	33.55	„
„	V.,	„ 2,346.9	„	„	53.10	„

Among cases in which the potash beds have been located, but sinking of shafts has not yet commenced, the following may be of interest :—

Hedwig is situated in the Prussian district Hehlingen, in the Province of Saxony, and covers a mining estate of about 3,000 acres. Three borings have been made, all of which have reached the potash beds at depths of about 1,320 feet. The potash deposits are continuous, and consist of kainite, in layers about 19 feet thick, by 450 feet wide and 6,000 feet long ; and carnallite, in beds about 30 feet thick, by 450 feet wide and 6,000 feet long. Below this level of 1,320 feet deeper extensive beds of carnallite have been found.

Neuhof-Romerz, near Fulda, has, by means of three borings, located the potash beds ; which, in borehole I., reached a thickness of 27 feet, principally consisting of carnallite and sylvine, and in another bed, below this, of 9 feet ; in borehole II., beds of 53, 25 and 9 feet thickness were found ; and in borehole III., beds of 66 and 7 feet thickness were found, consisting principally of sylvine.

Beständigkeit (Hermann II.) is situated near the railway stations Bornum and Königs-Dahlum, in Brunswick. The geological formation of this mine is a continuation of that of Carlsfund. The potash beds consist principally of carnallite of various thicknesses, and with an average richness of 16.49 per cent. K Cl.

Robertshall-Immenrode is situated in the Duchy of Schwarzburg-Rudolstadt.

Fig. 6. Works of the Potash Mines, Wilhelmshall.

Fig. 7. Shaft of the Potash Mines, Jessenitz, 1898.

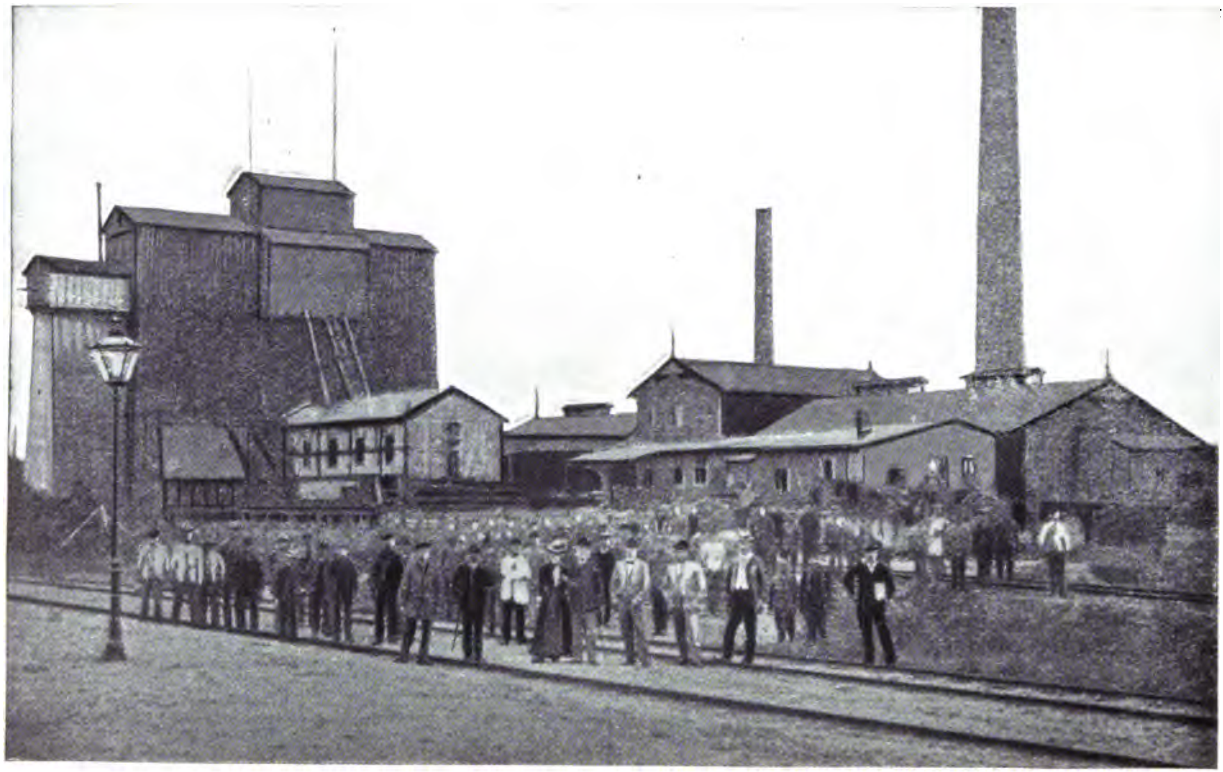


Fig. 8. General View of the Kaliwerke, Eime.

Professor H. Fresenius has given the following analysis of the potash salts :—

1.	545.25 *to*	546.00	metres	depth.	Potash,	11.48%,	representing	18.17%	K Cl.
2,	546.00	546.80	,,	,,	,,	11.60%	,,	18.36%	,,
3.	546.80	547.60	,,	,,	,,	12.09%	,,	19.13%	,,
4.	547.60	548.40	,,	,,	,,	10·72%	,,	16.97%	,,
5.	548.40	549.20	,,	,,	,,	11.01%	,,	17.42%	,,
6,	549.20	550.00	,,	,,	,,	10.66%	,,	16.87%	,,
7.	550.00	550.80	,,	,,	,,	10.94%	,,	17.31%	,,
8.	550.80	551.60	,,	,,	,,	11.24%	,,	17.79%	,,
9.	551.60	552.40	,,	,,	,,	10.50%	,,	16.62%	,,
10.	552.40	553.20	,,	,,	,,	10.41%	,,	16.48%	,,
11.	553.20	554.00	,,	,,	,,	8.91%	,,	14.10%	,,
12.	554.00	555.00	,,	,,	,,	10.49%	,,	16.60%	,,

Robertshall-Göllingen is also situated in the Duchy of Schwarzburg-Rudolstadt, having potash beds, consisting of carnallite, of 36 feet thickness, and containing on an average 17 per cent. K Cl.

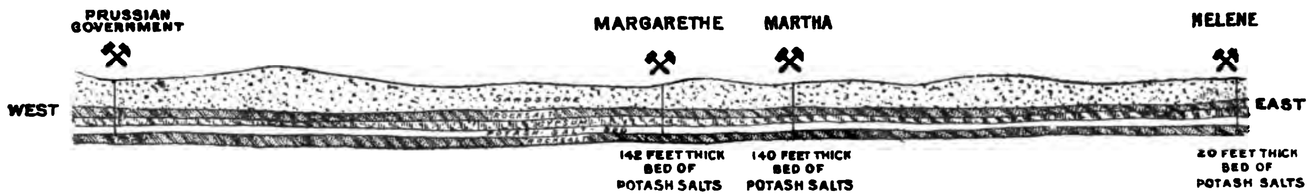
Hainrode is situated in the Prussian Eichsfeld district, in the Province of Saxony, and near to the Prussian Government's mine and works, Bleicherode. It covers an unusually large mining estate of about 7,850 acres.

The potash region has been found at an average depth of 1,860 feet, not only in one, but in four borings, named Heléne, Marie, Margarethe and Hainrode II. The thickness of the potash beds varies from 18 to 142 feet, and their continuity is unrivalled, either in the Thuringian or in the Hanoverian provinces; they consist entirely of carnallite. The quantity of potash salts, estimating the thickness of the beds at 45 feet only, is considerably greater than in any other private field, and sufficient to last for centuries at an output of 4,000 tons a day. The strata of the covering rock salt and sandstone appearing to be as regular as the potash beds themselves, there seems to be no difficulty in sinking shafts at low cost.

The geological structure is shown in Fig. 9, from which it will be seen that the potash beds run almost horizontally.

Fig. 9. Hainrode.

LONGITUDINAL SECTION OF FORMATION



LONGITUDINAL SECTION OF FORMATION.

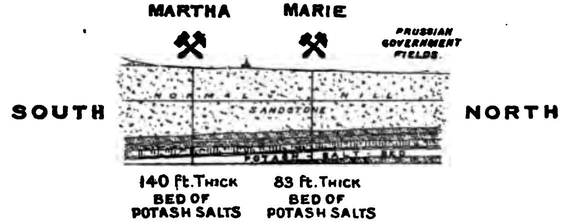


Fig. 10. Hainrode.

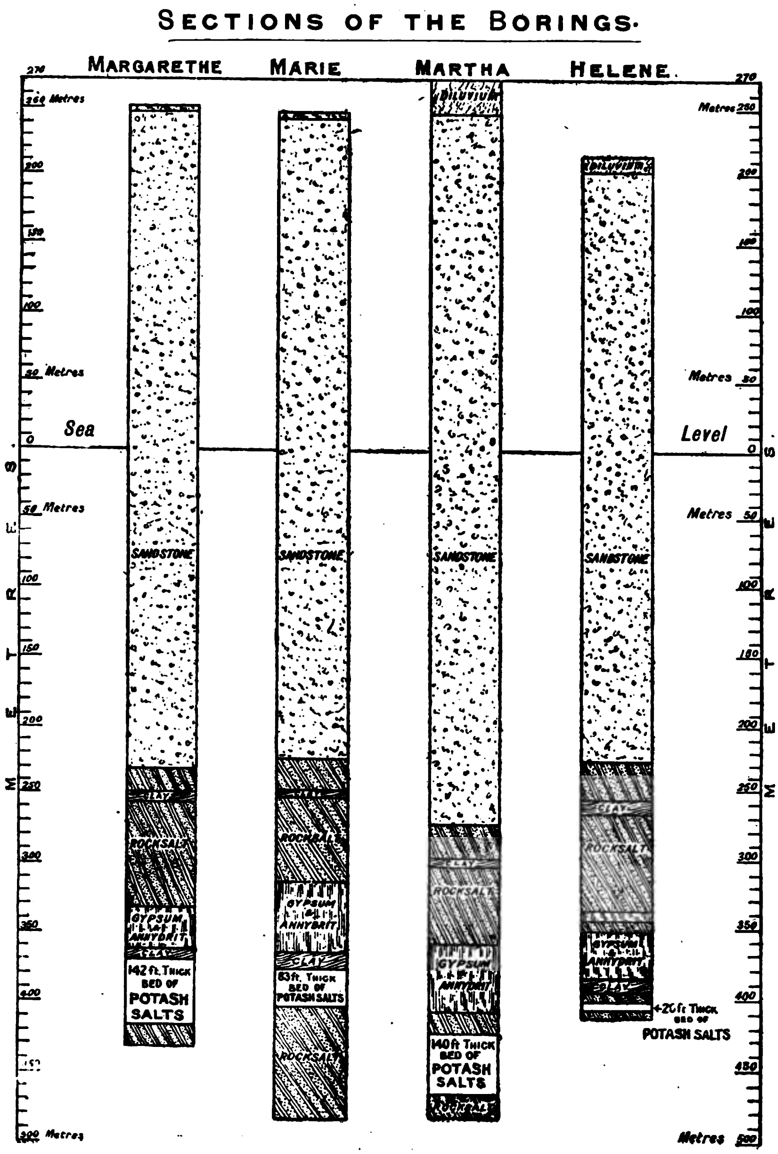


Figure 10 gives sections of the four boreholes, and the following tables give the composition of the various strata, as described by *W. Hoyer, Docent at the High Technical College, Hanover.*

1. **Helene,** Kl. Furra.

At 76.70	metres	depth	New red sandstone.
216.40	„	„	Chiefly slaty clay.
292.17	„	„	Chiefly slaty clay, with strings of gypsum.
400.07	„	„	Chiefly slaty clay, without strings of gypsum.
442.02	„	„	Red clay, with gypsum.
453.25	„	„	Light rock salt.
466.62	„	„	Rock salt, with bituminous anthracite clay.
478.22	„	„	Bituminous anthracite clay, with rock salt.
480.25	„	„	Bituminous anthracite clay.
484.04	„	„	Red rock salt.
546.48	„	„	Red and grey salt, with bituminous anthracite clay.
578.70	„	„	Grey rock salt, with anhydrite.
555.00	„	„	Anhydrite.
562,40	„	„	Grey salt, with anhydrite.
597.10	„	„	Anhydrite.
609.30	„	„	Bituminous anthracite clay.
614.90	„	„	Red and grey rock salt, with bituminous anthracite clay and anhydrite.
620.90	„	„	**Potash.**
626.00	„	„	Red rock salt, with anhydrite.

2. **Marie,** Hainrode.

At 3.50	metres	depth	Humus.
55.00	„	„	New red sandstone.
217.40	„	„	New red sandstone, chiefly blue clay.
359.65	„	„	New red sandstone, with strings of gypsum.
451.36	„	„	New red sandstone, chiefly blue clay.
461.02	„	„	New red sandstone, with fractions of gypsum.
470.50	„	„	Red clay with gypsum.
558.00	„	„	White, red and grey rock salt, with bituminous anthracite clay and anhydrite.
607.50	„	„	Anhydrite.
609.70	„	„	Anhydrite, with bituminous anthracite clay.
618.70	„	„	Bituminous anthracite clay.
623.80	„	„	Bituminous anthracite clay, with anhydrite.
851.50	„	„	**Potash.**
759.00	„	„	Red, white, yellow and grey rock salt.
730,30	„	„	Anhydrite and stony slate.

3. **Margarethe,** München Lohra.

At 2.00	metres depth	Humus.
17.00	,, ,,	New red sandstone.
227.38	,, ,,	New red sandstone, chiefly clay.
361.60	,, ,,	New red sandstone, chiefly clay, with string of lumps of gypsum.
433.15	,, ,,	New red sandstone, chiefly clay.
482.00	,, ,,	New red sandstone, chiefly clay, with slaty gypsum.
498.00	,, ,,	White and red rock salt.
581.80	,, ,,	Red and grey rock salt, with bituminous anthracite clay and anhydrite.
610.00	,, ,,	Anhydrite.
618.80	,, ,,	Bituminous anthracite clay.
666.30	,, ,,	**Potash.**
680.00	,, ,,	Grey rock salt.

4. **Martha,** Hainrode II.

At 170.00	metres depth	New red sandstone.
516.00	,, ,,	New red sandstone, with variegated clay.
544.00	,, ,,	New red sandstone, with variegated clay and gypsum.
564.00	,, ,,	Rock salt.
617.00	,, ,,	Grey rock salt, with anhydrite.
681.00	,, ,,	Anhydrite.
——	,, ,,	Black bituminous anthracite clay.
686.00	,, ,,	Grey bituminous anthracite clay, with strings of potash.
695.50	,, ,,	Anhydrite, with potash.
738.88	,, ,,	**Potash.**
742.63	,, ,,	Rock salt and potash.
754.00	,, ,,	Rock salt.

Dr. Brockhoff and Dr. Ehrecke, Analytical Chemists, Magdeburg, have made the following *analyses* of the potash salts :—

1. **Helene.**

Metres.		Chloride of potassium,	Chloride of sodium	Chloride of magnesium	Sulphate of magnesium	Anhydrous gypsum.	Insoluble.	Water.
614.90 *to*	615.25	21.60	18.16	20.00	8.00	2.05	4.69	25.50
165.25	615.70	16.44	34.90	17.24	8.33	1.58	1.07	20.90
615.70	616.05	15.36	46.20	17.24	—	1.10	0.08	20.60
616.05	616.25	15.50	43.32	17 19	2.76	1.61	0.24	15.50
616.35	616.75	12.78	48.39	15.65	2.78	1.32	0.95	18.25
616.75	617.10	14.80	43.78	15.68	4.56	1.56	0.96	18.70
617.10	617.45	15.20	38.72	19.21	2.42	1.94	0.58	22.30
617.45	617.80	14.78	43.27	1.62	1.63	1.93	0.57	20.60
617.80	618.30	14.39	48.50	15.58	1.32	2.05	0.27	15.80
618.30	618.80	11.84	52.04	13.40	2.37	2.33	1.86	15.80
618.80	619.12	14.79	42.19	18.19	1.56	1.78	1.06	20.90
619.12	619,57	7.84	72.06	4.42	0.59	2.96	6.82	5.80
619.57	619.90	13.29	48.33	15.94	1,83	2.32	0.12	18.50
619.90	620.45	11.38	49.83	14.13	5.43	1.64	0.55	16.80
620.45	620.90	10.60	55.42	11.89	0.69	3.50	4.08	13.90

2. Marie.

Metres.		Chloride of potassium.	Chloride of sodium.	Chloride of magnesium	Sulphate of magnesium	Anhydrous gypsum	Insoluble.	Water.
623.80 *to*	624.29	4.19	78.24	0.24	0.25	2.58	11.20	2.92
624.29	625.15	5.74	74.26	2.85	2.04	2.58	5.98	5.07
625.15	625.75	21.40	30.01	10.71	14.46	2.30	1.27	19.39
625.75	626.59	16.78	29.69	18.54	10.47	1.03	0.82	23.54
626.65	627.06	20.77	24.04	29.31	8.52	1.09	1.80	24.24
627.06	627.36	18.54	23.97	23.11	3.84	1.20	0.71	28.16
627.36	627.70	18.77	32.48	14.12	4.64	2.45	0.65	26.83
627.70	627.98	21.06	22.01	22.80	4.20	2.56	0.44	26.80
627.98	628.42	18.29	27.01	16.62	2.91	4.38	2.64	28.00
628.42	628.88	16.80	20.90	20.94	12.65	2.05	0.97	25.60
628.88	629.47	16.92	27.11	16.90	14.88	2.27	1.08	21.00
629.47	630.00	9.80	40.18	9.73	23.10	1.74	0.88	14.40
630.00	630.47	18.52	18.51	18.51	5.96	2.12	1.20	25.31
630.47	630.98	16.26	35.34	16.15	3.80	3.83	3.67	20.32
630.98	631.40	16.47	24.27	14.50	20.40	1.88	2.46	19.46
631.40	631.88	16.30	27.53	10.17	15.32	1.43	8.53	20.06
631.88	632.33	26.67	17.80	18.61	16.69	0.93	1.63	22.32
632.33	632.78	17.40	23.20	19.56	13.55	0.79	1.44	23.61
632.78	633.33	18.80	30.77	10.45	8.40	2.95	4.42	24.06
633.33	633.81	15.86	41.56	15.68	4.20	2.01	0.78	19.82
633.81	634.36	11.76	59.03	11.40	2.90	0.85	0.18	13.84
634.36	635.05	13.75	24.04	15.85	24.49	0.55	2.11	18.72
635.05	635 57	10.40	20.72	9.84	37.44	1.12	3.30	16.97
635.57	636.03	12.40	62,43	8.48	4.62	0.81	0.70	10.07
636.02	636.54	16.91	26.30	19.21	12.45	0.91	0.37	23.59
636.54	637 07	15.70	29.48	17.83	10.35	2.35	2.14	21.74
637.07	637.60	20.02	24.70	12.90	17.34	1.18	0.78	23.00
637.60	638.14	17.22	49.14	10.44	8.60	1 03	0.37	13.99
638.14	638.64	16.01	24.12	19.95	13.20	1.17	0.64	24.73
638.64	636.07	23.32	32.05	19.61	8.00	0.99	1.55	24.24
639.07	639.58	11.16	55.98	11.51	5.56	0.84	0.71	14.01
639.58	640.07	14.97	29.34	17.93	10.48	1.63	3.29	21.85
640.07	640.55	11.29	61.06	12.09	0.33	0.22	0.39	14.38
640.55	641.11	5.61	82.33	5.24	0.11	0.23	0.13	6.11
641.11	642.05	5.94	81.82	5.34	—	0.33	0.16	6.23
642.05	643.05	3.00	92.16	0.99	—	0.76	0.28	2.72
643.05	644.00	7.70	73.86	7.60	—	1.61	0.29	8.85
644.00	644.85	6.30	77.95	4.75	—	5.18	0.19	5.57
644.85	645.85	10.32	67.80	9.95	—	0.44	0.26	11.20
645.85	646.85	4.58	89.73	1 33	—	1.02	0.26	3.02
646,85	647.85	3.22	89.33	2.85	—	0.89	0.38	3.22
647.85	648.86	6.21	80.23	5.46	—	1.17	0.65	6.25
648.86	649.90	8.15	78.21	3.62	0.07	1.06	0.50	8.35
649.90	650.91	8.21	78.05	3.74	—	0.95	0.34	8.58
650.91	651.50	7.81	78.50	3.76	—	1.22	0.31	8.44

3. Margarethe.

Metres.		Chloride of potassium	Chloride of sodium	Chloride of magnesium	Sulphate of magnesium	Anhydrous gypsum	Insoluble	Water
619.30 *to*	619.75	26.20	8.01	28.44	0.10	1.72	0.77	34.05
619.75	620.25	26.62	3.61	31.13	0.26	2.14	0.51	35.61
620.25	620·75	26.41	10.61	27.45	—	1.02	0.21	34.35
620.75	621.20	22.75	12.56	24.70	1.56	3.08	5.58	29.60
621.20	621.70	20.50	17.78	24.70	0.02	4.88	3.67	28.10
621.70	622.50	21.82	12.24	27.45	3.13	1.89	2.06	31.00
622.50	622.65	20.45	15.16	24.53	3.82	2.03	6.01	28.30
622.65	623.11	19.23	13.10	27.45	5.53	1.20	2.18	31.80
623.11	623.61	22.90	12.37	27.12	1.13	1.13	2.13	30.94
623.61	624.11	21.93	14.73	26.55	3.65	1.31	1.79	30.50
624.11	624.61	23.47	14.05	25.89	3.53	1.23	2.65	29.85
624.61	625.06	21.24	13.79	26.57	5.19	0.92	1.46	30.85
625.05	625.91	23.36	5.84	29.05	5.90	0.96	0.89	38.74
625.91	626.91	24.55	5.18	30.48	1.30	2.51	1.46	34.70
626.91	627.97	22.08	12.28	26.80	6.43	1.47	0.69	31.27
627.97	628.90	25.15	5.26	30.02	0.43	3.43	1.59	34.15
628.90	629.40	20.70	18.51	22,13	9 47	1.09	1.10	27.65
629.40	630.35	22.18	23.12	19.81	5.35	1.44	0.52	27.56
630.35	631.30	20.31	30.33	23.71	5.39	0.48	1.48	27.28
631.30	652.30	21.16	21.65	24.00	2.52	2.02	0.86	27.70
632.30	633.20	20.69	22.64	24.00	0.46	3.22	1.26	27.69
633.20	634.15	19.10	11.69	22.82	16.25	0.61	0.63	29.06
634.15	635.15	20.40	18.39	25.27·	4.20	1.34	1.59	29.41
635.15	636.20	22.25	14.28	27.40	2.91	1.42	1.00	31.30
636.20	637.20	22.50	16.80	26.17	2.94	1.54	0.37	30.35
637.20	638.05	20.28	15.70	25.17	8.64	0.26	0.52	29.75
638.05	639 00	21.52	20.15	25.00	0.51	3.02	1.04	29.09
639.00	639.95	21.66	16.14	24.25	3.62	2.71	0.94	39.20
639.95	641.00	21.84	16.43	26.41	26.41	—	3.85	30.45
641.00	642.00	21.26	17.32	25.82	0.74	2.96	2 97	29.30
642.00	642.55	22.07	16.13	26.03	0.71	3.12	2.31	30.10
642.55	643.60	27.11	9.29	26.00	4.14	1.70	1.12	30.85
643.60	644.55	18.83	21.74	22.11	7.98	1.04	1.59	27.15
644.55	645.55	20.94	15.28	24.11	4.82	1.72	5.68	28.20
645.55	646.55	15.71	27.63	20.17	11.95	0.53	0.38	24.60
646.55	647.55	15.53	21.12	19.02	20.01	0.45	0.23	24.52
647.55	648.50	16.46	34.20	14.00	9.94	0.45	0.74	24.14
648.50	649.50	20.48	29.39	20.69	4.46	0.59	1.05	23.91
649.50	650.50	18.57	24.75	20.33	9.81	0.71	0.90	25.00
650.50	651.50	16.68	29.16	20.60	6.61	1.21	1.06	24.00
651.50	652.25	23.64	19.87	20.57	9.72	0.61	1.27	25.00
652.25	652.72	15.98	28.08	18.72	12.74	0.58	0.31	23.50
652.72	653.65	20 82	26.47	15.24	12.78	0.68	1.74	19.70
653.65	654.50	18.90	23.49	20.69	5.55	1.42	6.09	24.21
654.50	655.65	17.71	23.66	21.70	9.37	0.89	2.17	25.50
655.65	656.80	17.01	21.09	20.02	24.54	0.65	2.41	24.95
656.80	657.85	16.53	22.15	20.15	13.66	0.84	2.25	24.96
657.85	658.90	16.42	22.04	19.85	15.13	0.61	1.50	24.74
658.90	660.00	16,01	24.60	20.05	14.03	0.37	0.47	24.87
660.00	661.00	16.58	28.45	16.20	12.88	0.79	1.48	24.15
661.00	661.55	16.70	21.88	21.02	11.25	1.71	1.44	25.85
661.55	662.50	16.19	24.13	19.44	14.08	0.60	1.15	24.90
662.50	663.00	16.68	26.43	20.33	9.62	1.03	1.52	24.05
663.00	664.05	17.02	23·71	19.30	12.82	1.01	1.95	23.80
664.05	665.00	16.55	30·50	16.76	10.63	2.35	0.78	23.60
665.00	666.30	17.32	22.14	19.85	12.85	0.57	2.82	24.55

4. Martha.

Metres.		Chloride of potassium.	Chloride of sodium.	Chloride of magnesium	Sulphate of magnesium	Anhydrous gypsum.	Insoluble.	Water
695.28 *to*	695.85	18.65	24.60	22.31	1·58	3.57	0.84	28.44
695.85	696.42	16.80	24.78	17.16	11.18	2.27	1.33	26.21
696.42	696.99	18.70	21.14	22.23	6.85	1.45	0.61	29.21
696.99	697.56	18.55	21.12	19.26	11.27	0.98	0.80	27.87
697.56	698.13	17.50	24.29	19.47	8.76	1.11	0.82	27.76
696.13	698.70	19.80	22.63	21.34	4.65	2.06	0.27	29.53
698.70	699.27	20.20	20.00	24.66	3.52	1.50	0,57	29.16
699.27	699.84	18.40	31.24	16.96	10.70	0.63	0.77	21.36
699.84	700.41	19.00	24.21	23.19	4.39	1.09	1.46	26.96
700.41	700.98	16.90	21.62	21.55	11.91	1.02	0.53	26.87
700.98	702.12	19.30	19.08	22.55	9.89	1.52	0.40	27.18
702.12	703.26	21.40	13.91	23.50	7.14	2.63	0.28	31.32
703.26	704.40	24.20	14.56	26.58	0.57	1.32	0.29	32.71
704.40	705.54	17.40	23.70	19.53	2.67	2.82	3.24	30.19
705.54	706.68	21.75	27.20	17.74	3.56	1.34	1.26	26.75
706.68	707.82	13.92	32.80	15.34	9.12	2.21	1.66	24.60
707.82	708.96	16.00	46.39	5.82	15.01	2.60	1.47	12.47
708.96	710.10	20.85	14.71	25.63	6.56	1.01	0.27	30.67
710.10	711.24	24.57	5.16	28.84	5.90	0.84	0.30	34.57
711.24	712.38	21.40	18.75	24.09	6.46	0.46	0.34	28.94
712.38	713.52	20.90	13.33	26.62	2.68	1.10	1.88	33.14
713.52	714.66	16.90	19.28	24.02	4.56	1.20	0.55	31.84
714.66	715.80	16.80	29.13	18.02	8.49	2.61	0.70	24.65
715.80	716.94	14.80	25.44	18.14	17.03	1.33	0.28	23.44
716.94	718.08	16.65	24.00	19.28	14.72	0.41	0.28	24.27
718.08	719.16	17.20	30.25	18.36	10.94	1.06	0.24	22.51
719.16	720.24	16.20	28.29	16.13	16.88	0.49	0.26	22.00
720.24	721.32	21.20	39.63	13.21	8.31	0.76	0.39	16.72
721.32	722.40	13.60	50.30	7.00	17,01	0.41	0.27	11.23
722.40	723.48	15.05	34.30	19.08	6.47	0.67	0.25	23.76
723.48	724.56	16.30	23.81	18.70	15.18	0.29	0.50	24.92
724.56	725.64	16.40	18.04	18.35	19.59	1.59	0.95	24.97
725.64	726.72	11.90	44.85	12.48	9.29	0.67	0.49	20.41
726.72	727.26	13.25	42.50	15.00	7.33	0.84	2.22	18.80
727.26	727.80	16.00	40.32	17.85	2.10	0.51	0.45	22.98
727.80	728.34	13.95	44.90	16.40	2.65	0.75	0.97	20.40
728.34	729.96	13.70	54.50	13.04	2.04	0.68	0.45	15.14
729.96	731.58	15.95	38.12	17.32	4.06	0.92	0.42	23.41
731.58	732.66	15.80	40.89	18.40	2.13	0.68	0.68	21.30
732.66	734.52	16.65	46.72	12.00	3.47	0.84	0.44	19.28
734.52	736.88	15.85	41.61	17.16	4.00	0.76	0.65	20.14
736.88	738.86	15.80	32.83	19.31	6.36	0.98	0.49	24.67

(3) Companies engaged in Boring.

During the last few years there has been a great falling off in the number of exploration companies. At one time, the discovery of the outcrop of sandstone, or a salt spring, was sufficient excuse for putting down a test hole. Under the excitement of the time, capital was easily induced to take hold of such enterprises, many of which were organised rather for the purpose of speculation than from hopes of profitable exploitation.

FORMATION

of the

SALT DEPOSITS.

FORMATION OF THE SALT DEPOSITS.

The increase in the number of bore-holes, together with the simultaneous development of potash-salts obtained from the mines already working in the vicinity of Strassfurt, afforded valuable means for ascertaining the conditions under which the salt deposits had been formed. That they owed their origin to the evaporation of water in a sea or ocean was fairly certain, but the actual process seemed somewhat obscure, especially as the thickness of the deposits in some places reached 3,000 feet, whereas sea water containing 3 per cent. of solids (salt, &c.), even if the depth of the sea had been 30,000 feet, could only have deposited a salt bed of 450 feet in thickness.

It is probable that the sedimentation took place as follows :—

Thousands of years ago, the salt and potash deposits had their origin in a sea or ocean, the waters of which gradually receded, leaving, near the coast, lagoons or basins shut off from the ocean by means of sand or other obstacles, forming barriers of different heights and sections, over or through which occasionally there was a fresh influx of sea water whenever the walls or barriers were flooded or broken through, or by means of small channels which still preserved communication with the ocean. At that time, the Harz Mountain was an island, and as in that part of Europe the climate was then tropical, the waters of these lagoons rapidly evaporated, but were constantly replenished with fresh sea-water in the manner already described. Decade after decade this continued, until, by evaporation and crystallisation, the various salts present in the sea water were deposited in solid form. The less soluble material, such as sulphate of lime or anhydrite, solidified first and formed the lowest stratum. Then came a sediment of chloride of sodium (rock-salt), forming the rock-salt region. Then commenced the deposit of the most soluble salts of magnesium and potassium, which were the last part of the ingredients in the evaporating water to be deposited. Overlying the potash region is a bed of impervious salt-clay, acting as a water-tight roof to protect and preserve these very soluble compounds, which—had it not been for the existence of this superior stratum—would have been long ages ago washed away and lost by the action of the water percolating from above.

The salt-clay roof is covered by a stratum of anhydrite (sulphate of lime) of varying thickness, and again above this a second deposit of rock-salt (later formation), probably formed under more recent climatic and

atmospheric influences, or, possibly, by chemical changes in solution and subsequent precipitation. The salt deposit contains 98 per cent., or often more, of actual sodium chloride, a degree of purity rarely to be found elsewhere. Finally, above this are strata of gypsum, tenacious clay, sandstone and limestone, which crop out at the surface.

It must not be, however, inferred that the various strata succeed one another in regular order. They, indeed, occur according to certain well-marked physical and chemical laws, which, together with local conditions and geological disturbances, have fixed their relative positions. Yet as the order of formative influences has varied, so have the results occasioned interchanges in the strata, so that one deposit may be found in a higher position than another. At some few places surface-water has entered through cracks or fissures, and either entirely carried away the potash deposits, or changed them into secondary products. Consequences of this latter action are beds of kainite, sylvine and other less important compounds in the upper strata.

At the time of the depositing process the coast formation of the ocean or sea exercised an important influence on it, especially as regards the potash-salts.

Professor Vasit Hoff, of Berlin, and his pupils, have elaborately investigated the geological conditions of the Stassfurt salt deposits, and have explained them by the "phase rule" of Willard Gibbs. The researches are contained in some twenty-four papers published since the year 1897 in the proceedings of the Berlin Academy of Sciences. The subject is also dealt with by Vand der Heid (Leit. Phys. Chem. xii., 416), and by Löwenherz (Ibid, xiii., 459).

GEOLOGY of the POTASH SALTS.

GEOLOGY OF THE POTASH SALTS.

The first information regarding the structure and relation of the salt beds was derived from the mines in the vicinity of Stassfurt. The geological section shown here corresponds also, in general way, to that exhibited in all the mines of the Stassfurt-Westeregeln region (see Figure 11, page 52).

It may be termed the normal section.

'Essentially, it consists of extensive rock-salt beds, which overlie large deposits of anhydrite, and in turn are covered by Salzthon (salt-clay), anhydrite and the sandstone. The rock-salt beds are separated by intercalated strata of other minerals, into a series of lesser beds, which are commonly called "regions." These may be divided into four principal groups :—

(1) "**The Rock Salt Region.**"—The lowest stratum is formed of the less soluble material, such as sulphate of lime or anhydrite, which solidified first; then came common rock salt, with a slowly thickening layer which ultimately reached 3,000 feet, and is estimated to have been 13,000 years in formation. It is intersected by slender veins of anhydrite, gradually diminishing towards the top, and finally replaced by polyhalite, forming

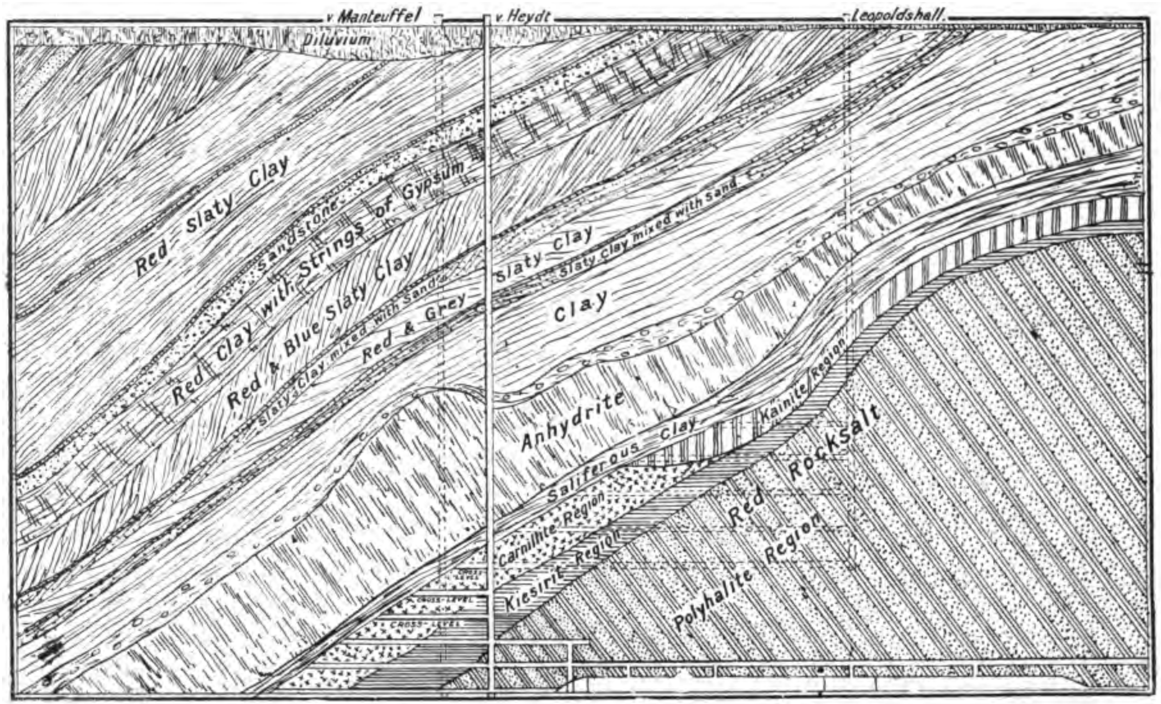
(2) **The Polyhalite Region,** still composed of rock salt, but intersected by veins of polyhalite, a mineral composed of sulphates of lime, magnesia and potash. This layer is about 192 feet in thickness, and consists, on the average, of

91·2% Chloride of sodium.
6·63% Polyhalite.
1·51% Hydrated chloride of magnesium.
0·66% Karstenite (anhydrite).

(3) **The Kieserite Region,** which now follows, is of a different composition, being characterised by the presence of a saline mineral named Kieserite, consisting of mono-hydrated sulphate of magnesium. The layer contains :—

65% Chloride of sodium.
17% Kieserite.
13% Carnallite.
3% Chloride of Magnesium.
2% Karstenite.

Fig. 11. Geological Formation of the Stassfurt Type.



The thickness of the bed is about 168 feet. Above the Kieserite lies

(4) **The Potash Region**, consisting mainly of deposits of Carnallite, a mineral composed of "muriate of potash" (potassium chloride) and chloride of magnesium.

Carnallite is the most important of the crude potash salts, and is, by reason of its highly hygroscopic nature, used solely for manufacturing purposes. The region is characterised by considerable uniformity, and is of large extent, so that, notwithstanding the variable chemical composition, it is to be considered the basis of the mining and chemical industry. The rock occurs in a variety of colours; it may be clear and transparent, or of any shade of yellow, red, grey, or black, owing to impurities such as oxide of iron, clay, organic matter, &c.

There are found also in this deposit Sylvine and Howellite, chlorides of potassium, containing often small quantities of sulphate of potash and sulphate and chloride of magnesium; Tachydrite, a carnallite in which the chloride of potassium is replaced by chloride of calcium; and Boracite, a combination of the borate and chloride of magnesium. For formulæ of these minerals see pages 63 and 64.

These salts, however, appear only where the strata have been bent or folded. They occupy the highest part of the saddles, so that it would appear they are not original deposits, but have been formed by secondary crystallisation out of the carnallite. This is further attested by the fact that carnallite, when dissolved in water, suffers decomposition, and can only be crystallised out of a solution containing at least 25 per cent. chloride of magnesium.

In the Stassfurt section, the region of carnallite and its decomposition-products is overlaid by the Salzthon (saliferous clay), which acts as a protective mantle. Over this lies a bed of anhydrite, the highest member of the Zechstein (Permian limestone) formation. It also has served to protect the salt beds from being carried away in solution.

In many places the anhydrite stratum contains extensive rock-salt deposits that are usually characterised by a coarse crystalline texture and remarkable purity. These deposits are commonly called "later rock-salt," in contrast to the other formation which is associated with potassium salts.

The potash deposits are always found associated with rock-salt. Beds of the latter occur in all parts of the world, and in various geological formations, but potassium salts and the accompanying

magnesium salts have so far been discovered only in the Zechstein formation (Dyas) of Germany. The beds occur in the upper part of the Zechstein, and are covered by the Triassic sandstone. The Zechstein, and especially its upper salt-bearing member, extends over a large territory in northern and middle Germany. The rocks are seldom found outcropping, and it is to this and to the covering Bunter Sandstone (lower Trias) that the preservation of these easily soluble salts is due.

In the mountainous parts of Germany the strata give way to large areas of older rocks, and around the edges of such areas the Zechstein outcrops in the form of limestone, anhydrite, gypsum and clay, which are more resistant to weathering influences. The borders of the Harz and of the Thuringian Forest, and the western side of the Westphalian Schistose region, are thus formed by the Zechstein.

It is evident from the geological aspects that those regions are more likely to contain deposits of potash salts, whose surfaces are covered by the sandstone, as this rock in most cases lies directly over the Zechstein deposits, and it is here that the latter may be looked for at the least depth.

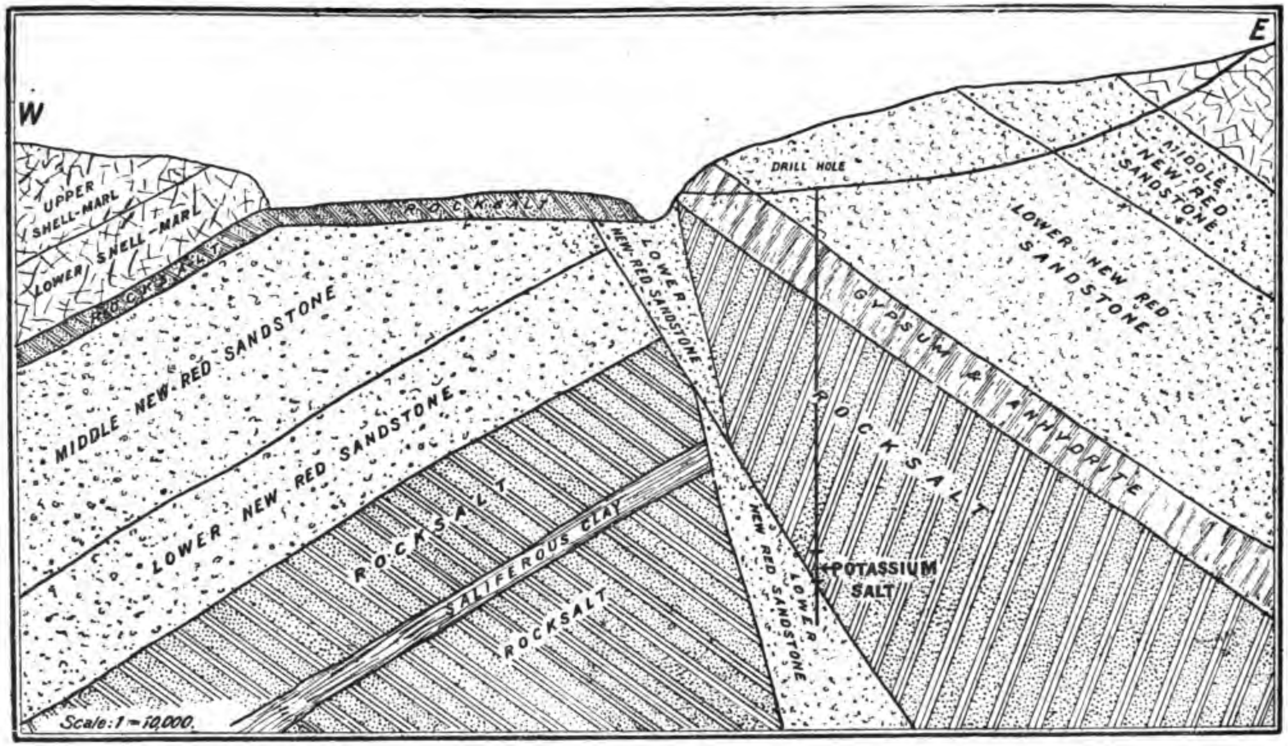
This principle has been of much service in exploring the region west of the Rhine and north of the Main, and it has been found that the Zechstein is almost invariably accompanied by rock salt, but only in certain cases by potassium and magnesium.

The territory in which the potash deposits are most frequently found is that surrounding the Harz, the Provinces of Hanover and Saxony, and also the Duchies of Anhalt and Brunswick. Explorations have been carried out also, with more or less favourable results, in the Thuringian Forest region, near Osnabrück, and in the Allerthal, between Magdeburg and Celle.

The potash-bearing regions are subdivided by Hoyer into the following *geological provinces* :—

(1) **The Saxon Province.**—The deposition of the "Abraum salts" (page 10) has here followed a perfectly regular course. The firm coast lines of the strongly-built palæozoic strata of the Harz Mountain and the shore of the Magdeburg basin, which were in existence before as well as during the depositing process, favoured a calm tide and a normal evaporation, and enabled the deposits to increase with singular evenness. The salts, therefore, occur in typical sequence, and are covered normally by the mesozoic strata. These special features of the Harz and of the Magdeburg basin account for the fact that, later on, especially

Fig. 12. Geological Formation of the Hanover Type.



during the period of the intense dislocations of the Miocene, the salt deposits and their hanging walls were well protected against destructive influences, such as ruptures and the consequent influx of water. Even to the present the salt beds are nearly all very well preserved, even where the dip of the strata is unusually steep.

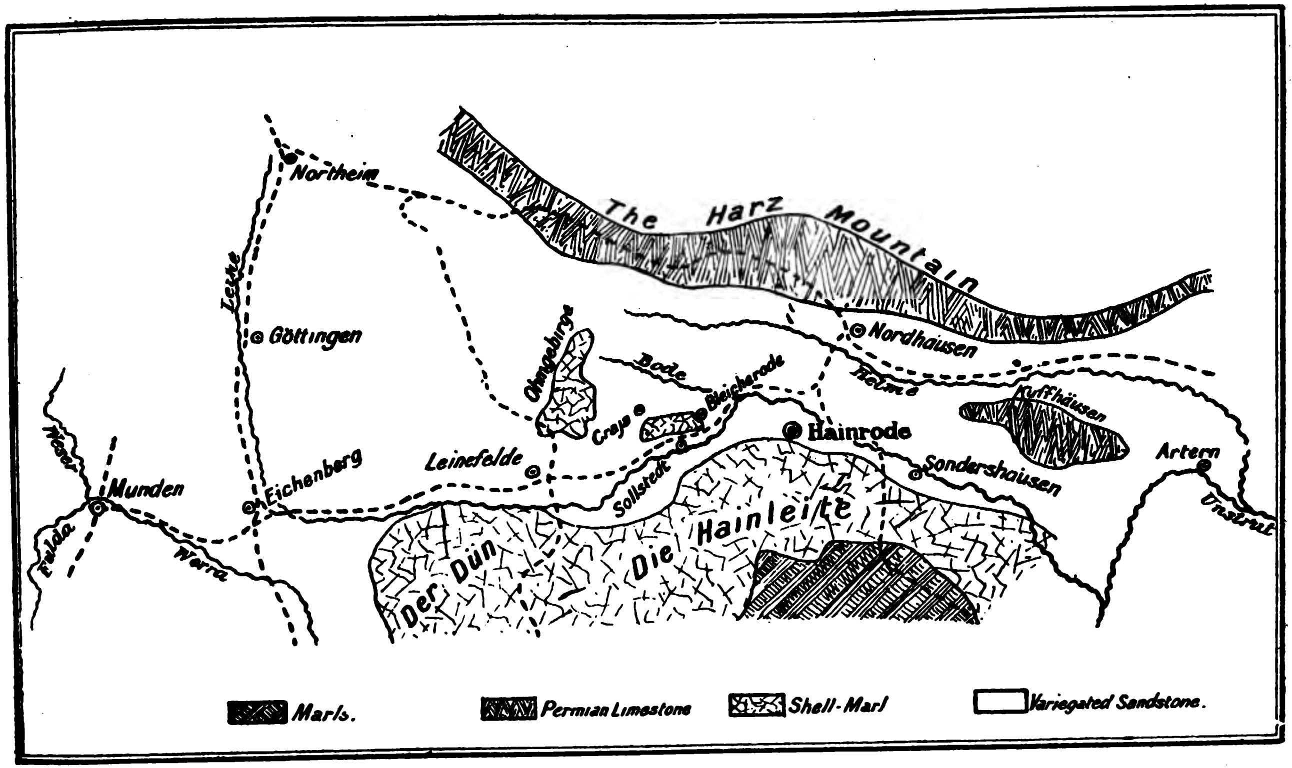
(2) **The Hanoverian Province** comprises the Grand-Duchy of Mecklenburg-Schwerin, the Duchy of Brunswick and the political province of Hanover. Here the coast-lines were evidently far less favourable at the time of the depositing process, the basins being wide and without regularity, and the channels long, narrow and irregular; consequently a more or less constant influx from the sea was permitted. The sedimentation was, therefore, frequently interrupted, and newly-formed beds appear to have been repeatedly carried away, an occurrence which is more and more visible the greater the distance from the Harz mountains. Clearly during the later convulsions the salt deposits covered by the mesozoic strata suffered from the want of massive supports, since they were tilted, broken up and scattered in the most extensive manner, so that it is exceedingly difficult in this province to determine the position of the various deposits. In many cases there was a far reaching subsequent erosion of the salt-beds by means of water penetrating through the fissures. On the whole the salt-beds of the province represent a much interrupted and widely scattered, though geologically interesting, area of rock-salts and potash, the latter appearing in many cases to be of great richness in chloride of potassium.

(3) **The Thuringian Province.**—Movements of the water, during the period of deposition, seem to have been here comparatively regular, as in the whole western district of the Thuringian Forest the borings have shown potash beds of a perfectly normal character, proving that the accumulations occurred under the protection of firm, unchanging coast-lines, while no doubt there were palæozoic strata of the Thuringian Forest and of the old mountains to the west of it, standing, from the commencement, in a position favourable to salt-bed formation.

The exploitation of the salts of this province has not yet commenced, but borings have shown that they frequently differ both chemically and in geological arrangement from those of the provinces (1) and (2). Estimates of the prospects of potash mining in Thuringia are, therefore, unsafe.

During the later geological periods the land of the district has

Fig. 13. Plan of the Eichsfeld Basin.



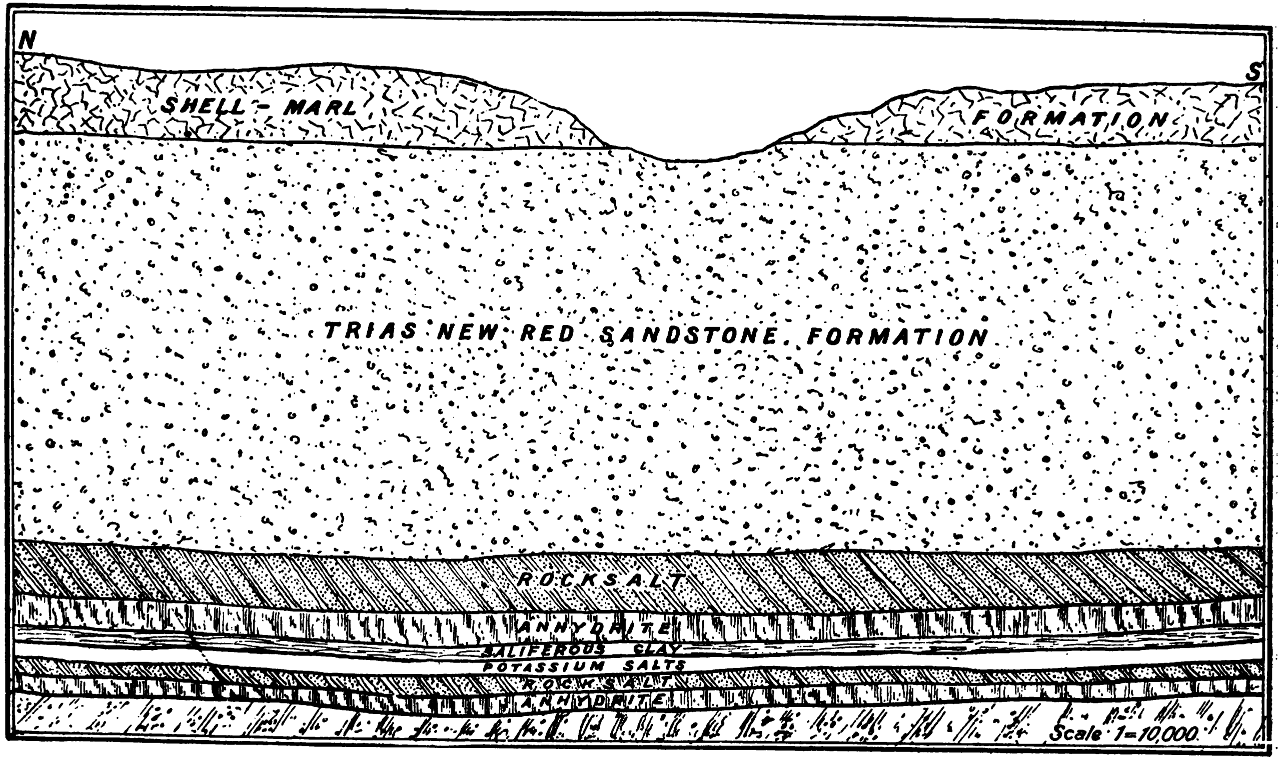
evidently undergone considerable subsidence, greater towards the west than elsewhere, while at the Miocene era the subsided portions have been occasionally disturbed and shattered, evidenced by the steep, or even vertical, position of the strata in some places, and the level but ruptured state in others. The strata obviously had not the advantage of the protection of the older mountain ranges to the west during the course of the sedimentation, as they seem to have partially subsided even before the commencement of the tertiary movements, and dislocations even now can be traced.

(4) **The Eichsfeld Province** includes the district lying between the Harz and the Thuringian Forest. To the east it probably reaches some distance beyond the Kyffhauser Range, to judge from the salt deposits which have already been found. To the west the Harz is the boundary. Within this province the sedimentation of the rock-salt and the potash has taken place as regularly as in the Saxon division. The great ranges of the Harz, and probably also of the Thuringian Forest, have acted as protecting coast-lines, which have regulated the movement of the water. In the centre of the district, in particular, the depositing process has been quite undisturbed, whereas, in the more outlying parts of the east and to the west, the sedimentation seems to have been unequal (see figs. 13, 14).

A normal course has also attended the growth of the hanging walls of salt in the central part of the district. Whilst, on the one hand, the neighbouring portions of the Hanoverian and Thuringian provinces were subjected, even at a later period, to very considerable subsidences and faults, the central area of the Eichsfeld has been much less exposed, and has evidently been, to a great extent, protected by the Harz against the influences of the Miocene period; consequently the Prussian part of Eichsfeld exhibits an unusually level disposition of strata over a large proportion of its extent. In this narrower district it is to be noted that the salt deposits and their covering mountains have not experienced any fissures, such as have afforded the water free access to the salt beds in most of the outer districts, resulting in the entire destruction of the deposits, as is the case even in the Hanoverian Eichsfeld, in proximity to the Prussian section.

The Prussian Eichsfeld, therefore, comprises a mountain-complex with a normal sedimentation, strata in good preservation, of small gradient and with well-developed coverings over extremely valuable deposits of potash-salts.

Fig. 14. Geological Formation of the Eichsfeld Type.



MINERALOGY

of the

POTASH

SALTS.

MINERALOGY OF THE POTASH-SALTS.

Omitting consideration of the gypsum, anhydrite and rock-salt, the minerals found in the deposits may be divided, according to their chemical composition and commercial use, into two groups: the potassium and the magnesium salts; a few, of lesser importance, do not come under either head. Further, in regard to origin, they may be classed as primary and secondary salts, the latter including such as have arisen from the solution and reprecipitation of the older deposits. The classification cannot be sharply drawn, as carnallite and sylvine for instance occur both as primary and secondary products. The primary salts are often coloured reddish through inclusion of thin laminæ of hematite; the secondary are lighter in colour and much more pure.

Carnallite, $K\,Cl$, $Mg\,Cl_2$, $6\,H_2O$, is the most important of the potassium salts, both as regards quantity and uniformity of distribution, and may be almost said to be the mineral basis of the industry. In a pure state it contains K Cl 26·8 (equal to 14 per cent. K), $Mg\,Cl_2$, 34.2, and water 39 per cent. but, in nature it is almost always associated with more or less rock-salt, kieserite and other minerals, by which the percentage of K Cl may be reduced to less than half the theoretical amount. It is also the most important of the primary minerals, but now and then occurs as secondary, and is then very pure. It is usually coloured reddish (whence the name) by the presence of small scales of hematite; yellow and pure white varieties are very seldom found, and then only in the secondary beds. It is easily soluble in water, but suffers decomposition, a characteristic which is made use of in chemical manufacture.

Sylvine, K Cl, is richer in potassium than carnallite, containing 52·46 per cent. K. In the Stassfurt mines it is of secondary origin, being derived from the decomposition of carnallite, while it is a primary constituent of the Hanover and Brunswick deposits. When mixed with considerable amounts of rock-salt it is called *Sylvinite.* Its colour is white, yellow or red, the first variety being the most common.

Kainite, $K\,Cl$, $Mg\,SO_4$, $3H_2O$, formed by the decomposition of carnallite, is the most important of the secondary minerals, and is widely distributed in the mines of the Stassfurt district. When not too impure it can be ground and used directly for agricultural purposes. It is usually, however, mixed with considerable amounts of rock-salt, and

is then called *Hartsalz*, a name which is commonly applied, also, to potassium-magnesium salts, containing rock-salt, but no magnesium chloride. These require chemical treatment before they are commercially valuable.

Schoenite or **Pikromerite**, $K_2 SO_4$, $Mg SO_4$, $6 H_2O$, is a secondary product of carnallite, less widely distributed than Kainite.

Polyhalite, $K_2 SO_4$, $Mg SO_4$, $2 Ca SO_4$ $2 H_2O$, is interesting through its occurrence in the form of bands within the so-called polyhalite region. It is at present of no commercial importance.

Kieserite, $Mg SO_4$, H_2O, is the most important and extensively distributed of the magnesia salts. It is a shining, yellow mineral, easily decomposed by water, thereby forming Bitter salts, Reichardtite or Epsomite, $Mg SO_4$, $7 H_2O$.

Among the other potassium and magnesium salts of less technical significance may be mentioned: Glaserite, K_2SO_4; Krugite, K_2SO_4. $Mg SO_4$, $4 Ca SO_4$, $2 H_2O$; Bischofite, $Mg Cl_2$, $6 H_2O$; Tachydrite, $2 Mg Cl_2$, $Ca Cl_2$, $12 H_2O$; Astrakanite (Bloedite), $Na_2 SO_4$, $Mg SO_4$, $4 H_2O$; and Douglasite, $2 K Cl$, $Fe Cl_2$, $2 H_2O$. The latter mineral is remarkable for the fact that it readily decomposes with the evolution of hydrogen in large quantities.

Of other substances containing no potassium, but of scientific or technical interest, the following are deserving of mention: Anhydrite or Karstenite, $Ca SO_4$; Boracite or Stassfurtite $2 Mg_3B_8 O_{15}$, $Mg Cl_2$, in nodules, within the carnallite region; Pinnoite, $Mg B_2 O_4$, $3 H_2O$; Glauberite, $Na_2 SO_4$, $Ca SO_4$; Sulphur, pyrites and hydrogen sulphide, H_2S. The last mentioned is often a source of great danger to miners.

It is extremely difficult and often impossible to distinguish the different minerals by mere inspection, and for this purpose, as well as to arrive at the value of the different salts, it is absolutely necessary that chemical analysis go hand in hand with the mining.

GERMAN
POTASH
SYNDICATE.

THE GERMAN POTASH SYNDICATE.

The world's supply of potash-salts, with the exception of saltpetre, continues to be derived from Germany, where the production is controlled by the "Verkaufs-Syndikat der Kaliwerke, Leopoldshall-Stassfurt," generally known as the "Kali-Syndikat," or in English "The German Potash Syndicate," which was organised by all the active mines for the protection of the common interests of the industry.

The Syndicate does not derive any profit from thus controlling and managing the businesses, the contributions of the several mines being limited to the actual expenses, in proportion to the output of each.

The agreement first entered into (in 1879) between the Syndicate and the respective mines then working, has been renewed and revised from time to time ; the last renewal dates from 21st December, 1901, and is to run for three years.

Under this arrangement the marketable products are divided into three classes :—

(1) Crude salt, that is potassium and magnesium products from the mines, not including Boracite ;

(2) Manufactured products, so far as they are prepared in the chemical works connected with the mines ;

(3) Mixed salts, mixtures of crude and prepared salts, for fertilisers.

The "Kali Syndikat" by its agreement determines not only the sale and the prices of the different products, but it has also decided the exact quantity which each mine may contribute to the total output.

In this connection the products of the mines are divided into four classes, according to their percentage of potassium, as follows :—

Class I.—Products with more than 48 per cent. Potash, K_2O, an equivalent of 76·1 per cent. K Cl or 88·9 per cent. K_2SO_4.

Class II.—Products with not more than 48 per cent. K_2O, nor less than 18 per cent., equivalents of 76·1 to 28·5 per cent. K Cl or 88·9 to 33·3 per cent. K_2SO_4.

Class III.—Crude salts (not carnallite) with 12·4 to 18 per cent. K_2O, equivalents of 19·7 to 28·5 per cent. K Cl or 23·0 to 33·3 per cent. K_2SO_4.

Class IV.—Carnallite salts with less than 12·4 per cent. K_2O.

The percentage of potash is made the basis for determining the amount of salts of each kind which any manufacturer may offer for sale, but no restrictions are put on the output of the crude material so long as it does not come into the market.

Class I. includes mostly refined products; Class II. both refined and crude; Class III. and IV. crude only.

A method for separating Classes III. and IV. has been adopted, and will prevent carnallite salts, which contain a high percentage of potash, being sold under Class III. It is based upon the relative solubilities of carnallite and kainite in 96 per cent. alcohol, the magnesium chloride in the kainite being insoluble, while it is soluble when occurring in carnallite. Salts which contain more than 6 per cent. soluble chlorine are put in Class IV.

The output of the 20 mines which are now co-operating under the Potash Syndicate, has been fixed for the three years, 1902, 1903 and 1904, and distributed amongst them as shown in the following table.

Distribution of the Output between the Mines.

YEAR.	1902.				1903.				1904.			
	Class.				Class.				Class.			
MINES.	I.	II.	III.	IV.	I.	II.	III.	IV.	I.	II.	III.	IV.
Government of Prussia	96.96	96.71	87.82	98.18	96.73	96.49	87.34	98.18	96.48	96.23	86.37	98.18
,, Anhalt...	88.01	87.78	81.07	76.05	87.80	87.58	80.63	76.05	87.57	87.35	79.73	76.05
Westeregeln	74.59	74.39	68.92	69.12	74.41	74.22	68.54	69.12	74.22	74.03	67.77	69.12
Neustassfurt	74.59	74.39	68.92	69.12	74.41	74.22	68.54	69.12	74.22	74.03	67.77	69.12
Aschersleben ...	74.59	74.39	68.92	69.12	74.41	74.22	68.54	69.12	74.22	74.03	67.77	69.12
Ludwig II.	53.70	53.55	22.28	55.32	53.51	53.43	22.16	55.32	53.44	53.29	21.91	55.32
Hercynia	74.59	74.39	68.92	69.12	74.47	74.22	68.54	69.12	74.22	74.03	67.77	69.12
Solvaywerke	74.59	74.39	68.92	69.12	74.41	74.22	68.54	69.12	77.22	74.03	67.77	69.12
Thiederhall	34.31	34.22	—	37.04	34.23	34.14	—	37.04	34.14	34.05	—	37.04
Wilhelmshall	53.70	55.53	59.99	54.45	53.57	55.40	59.66	54.45	53.44	55.26	58.99	54.45
Glückauf	39.77	39.66	49.28	37.04	39.68	39.57	49.00	37.04	39.58	39.47	48.46	37.04
Hedwigsburg	33.80	33.80	46.10	37.04	33.72	33.73	45.85	37.04	33.64	33.64	45.34	37.04
Burbach	31.70	31.70	39.67	37.04	31.63	31.63	39.45	37.04	31.54	31.55	39.01	37.04
Carlsfund	31.70	31.70	41.69	37.04	31.63	31.63	41.47	37.04	31.54	31.55	41.00	37.04
Beienrode	33.10	33.10	23.24	37.04	33.02	33.02	23.12	37.04	32.94	32.94	22.86	37.04
Asse	31.70	31.70	41.69	37.04	31.63	31.63	41.47	37.04	31.54	31.55	41.00	37.04
Salzdetfurth	37.56	37.56	44.07	37.04	37.47	37.47	43.84	37.04	37.37	37.37	43.34	37.04
Jessenitz	32.87	32.87	—	37.04	34.23	34.14	—	37.04	34.14	34.05	—	37.04
Hohenzollern	28.17	28.17	33.50	37.04	29.04	29.04	33.31	37.04	31.54	31.55	38.14	37.04
Justus I....	—	—	85.00	—	—	—	90.00	—	—	—	95.00	—

The figures in each column represent the contribution of each mining company per 1,000 metric tons of total output.

The following table will show the annual production of the various kinds of salts :—

Total Output of Crude Salts in Metric Tons.

Year.	Carnallite.	Rock Kieserite.	Sylvinite.	Hartsalz and Kainite.	Total.
1861	2,293	—	—	—	2,293
1862	19,727	20	—	—	19,747
1863	58,304	68	—	—	58,372
1864	115,409	89	—	—	115,498
1865	87,671	75	—	1,314	89,060
1866	135,554	414	—	5,808	141,776
1867	141,604	1,144	—	8,974	151,722
1868	167,337	1,418	—	10,772	179,527
1869	211,884	227	—	16,857	228,968
1870	268,226	71	—	20,301	288,598
1871	335,945	47	—	36,582	372,574
1872	468,538	23	—	18,067	486,628
1873	441,079	8	—	6,101	447,188
1874	414,961	16	—	9,753	424,730
1875	498,737	5	—	24,124	522,866
1876	563,669	145	—	17,938	581,752
1877	771,819	152	—	35,477	807,448
1878	735,750	520	—	34,004	770,274
1879	610,427	761	—	50,207	661,395
1880	528,212	893	—	139,491	668,596
1881	744,726	2,082	—	158,330	905,138
1882	1,059,300	4,658	—	148,477	1,212,435
1883	950,203	11,791	—	228.817	1,190,811
1884	739,959	12,389	—	217,107	969,455
1885	644,710	11,970	—	272,370	929,050
1886	698,229	13,918	—	247,327	959,474
1887	840,207	14,186	—	237,629	1,092,022
1888	849,603	10,754	2,220	375,574	1,238,151
1889	798,721	9,354	28,329	362,611	1,199,015
1890	838,526	6,951	31,917	401,871	1,279,265
1891	818,862	5,816	32,661	512,494	1,369,833
1892	736,751	5,783	32,669	585,775	1,360,978
1893	794,660	4,807	49,140	689,994	1,538,601
1894	851,339	3,865	63,495	729,301	1.648,000
1895	782,944	3,012	76,097	669,532	1,531,585
1896	856,223	2,841	90,390	833,025	1,782,479
1897	851,272	2,619	84,105	1,012,186	1,950.182
1898	990,998	2,444	94,270	1,120,616	2,208,328
1899	1,317,948	2,066	100,653	1,063.195	2,483,862
1900	1,697,803	2,047	147,791	1,189,394	3,037,035

Application of the Crude Potash Salts in Metric Tons.

Year.	Carnallite and Rock Kieserite.				Kainite and Sylvinite (including Hartsalz).			
	For Agricultural Purposes.		For Manufacturing Concentrated Salts	Total.	For Agricultural Purposes.		For Manufacturing Concentrated Salts.	Total.
	Germany.	All other Countries			Germany.	All other Countries.		
1880	4,137	—	524,968	529,105	23,769	103,749	11,973	139,491
1881	6,902	—	739,906	746,809	20,372	119,491	18,467	158,339
1882	10,249	—	1,053,709	1,063,958	30,414	95,263	22,800	148,477
1883	17,434	—	944,560	961,994	48,138	153,200	27,479	228,817
1884	18,654	—	733,694	752,348	48,644	109,656	58,8 7	217,177
1885	18,988	—	637,692	656,680	50,870	143,518	77,982	272,370
1886	22,729	—	689,418	712,147	65,835	105,050	76,441	247,326
1887	30,892	—	823,501	854,393	84,493	89,294	63,842	237,629
1888	31,776	—	828,580	860,356	105,237	142,171	130,386	377,794
1889	37,746	382	769,947	808,075	150,342	113,109	127,489	390,940
1890	34,574	373	810,530	845,477	178,031	126,984	128,772	433,787
1891	38,893	551	785,234	824,678	240,001	173,508	131,647	545,156
1892	45,367	1,253	695,913	742,533	366,661	131,912	119,871	618,444
1893	59,464	3,483	732,233	795,180	428,891	184,358	125,885	739,134
1894	60,893	4,117	790,193	855,203	466,208	200,240	126,348	792,796
1895	50,528	3,836	731,582	785,946	436,923	190,732	117,975	745,630
1896	56,541	3,964	798,560	859,065	557,527	245,060	120,829	923,416
1897	58,544	5,157	790,190	853,891	668,340	295,765	132,185	1,096,290
1898	60,793	7,189	925,461	993,443	722,115	334,111	158,660	1,214,886
1899	58,677	4,611	1,256,730	1,320,018	717,637	314,869	131,342	1,163,848
1900	55,489	2,869	1,641,493	1,699,851	724,624	375,007	237,554	1,337,185

The mines employ about 7,000 miners and over 9,000 labourers in the chemical works connected with the mines.

Some 300 scientific and technical experts guide this army of workers, and to cope with the correspondence a proportionally large clerical staff is required.

The works are supplied with 642 steam boilers, representing about 66,564 horse power, and 924 steam engines of 59,420 horse power.

The *combination of the working potash mines into a Syndicate or Trust Company* has enormously increased their business, not only in regard to production and disposal, but also in respect of utilisation of the potash-salts ; particular advantages having been given to German industry and agriculture in form of greatly reduced prices, almost at cost of production, whilst countries outside of Germany have to pay abnormally high prices for their requirements of potash-salts, the Syndicate being thereby shown to be fully cognisant of the full value

of its monopoly. The great disadvantages arising out of such procedure towards foreign agriculture and industry are apparent, and so far as agriculture is concerned, very injurious, since the farmers seem to prefer to be content with the supply to them of phosphates and nitrates alone, leaving out the use of potash altogether, although they may be cognisant of the fact that potash-salts are an indispensable manure for every crop.

Nevertheless, it should not be forgotten that the Potash Syndicate also does a great deal of good work by annually spending great sums of money towards the cost of scientific researches and in making propaganda in most of the civilized countries, for spreading knowledge and emphasising the use of potash-salts. It is interesting also in this respect to follow the work of the Potash Syndicate. It has been stated in "Der Montanmarkt, 16th April, 1902," that various agricultural societies in Germany received during 1899 a total sum of 589,460 marks (£29,473), which increased to 596,762 marks (£29,838) in 1900, and other German channels received for the same purpose 117,500 marks (£5,875) in 1900, and 151,200 marks (£7,560) in 1901, a similar sum having been provided also for the year 1902 for propaganda on behalf of the Syndicate. In the United States of America the expenses for the same purpose amounted to 159,136 marks (£7,959) in 1900, as against 190,100 marks (£5,505) in 1901, the amount for 1902 having been fixed at 243,623 marks (£12,181). The total amount of expenditure under this heading and management has been estimated at 1,200,000 marks (£60,000) for 1902, as against 1,000,000 marks (£50,000) during 1901. Besides this, great labour, in connection with considerable expense, is being spent in opening up new markets for the potash-salts, particularly in North, Central and South America, 50,000 marks (£2,500) having been set aside for this purpose for Chili, Peru and Brazil alone, whilst very little has been done as yet for the introduction of the potash-salts into the British Colonies, Australia, Africa, Canada and India.

This work, in conjunction with so great an expenditure, has had the desired effect in affording to the Syndicate a result of highly remunerative character, strikingly evidenced by the statistical tables, a few extracts from which, during the last ten and five years respectively, or from 1891 to 1900, and from 1895 to 1900 inclusive, will more clearly demonstrate this :—

The **production** has been in the years mentioned :—

	1891	1901	Increase	
Potash salts ... ... tons	1,369,833	3,037,035	1,667,202	122%
Carnallite and kieserite	824,678	1,699,851	875,173	106%
Kainite and sylvinite	545,156	1,337,185	792,029	164%
Potash manure salts	16,045	129,863	113,828	700%
Value of potash products ... £	1,185,510	2,785,747	1,600,237	135%

The prices of the salts decreased by little and little from 21.99 marks per 100 kilo. in 1899 to 17.87 marks in 1898, since when it has regularly increased to 18.51 marks in 1899 and 19.06 marks in 1900.

The **Consumption** of potash-salts per 100 acres of arable land has also increased, for instance, in—

	1895	1900	Increase	
Germany ... ... Tons	152.5	298.3	145.8	82%
Scotland	77.3	204.0	126.7	164%
England	33.3	52.4	19.1	57%
Ireland	10.6	24.8	14.2	134%
United States of America	21.5	42.2	20.7	96%

The greatest part of the annual production of potash salts is used as manure in agriculture, whilst a smaller proportion is being utilized for industrial purposes, and although the consumption greatly increases every year, it represents, nevertheless, an insignificant part only of that which is actually required for Europe, as well as for the United States of America and other countries ; it is, therefore, evident that the potash industry is just in its infancy.

It may be of interest to give below the figures, just published in **The Annual Report by the Potash Syndicate for 1901,** showing the production of the various salts during the years 1896 to 1900.

The sale of the various kinds of potash salts during 1900 was as follows :—

191,421.6 tons muriate of potash, at 80 per cent.

31,255.0 „ sulphate of potash, at 90 per cent.

12,150.0 tons calcined sulph. of potash-magnesia, at 48 per cent.
881.6 „ crystallized „ „ at 40 per cent.
125,088.6 „ potash manure salt.
358.3 „ kieserite, calcined.
28,507.5 „ „ in blocks.
1,099,631.4 „ kainite and sylvinite.
58,358·0 „ carnallite and kieserite.

The **distribution** of the various potash salts amongst the respective countries, during the last five years, has been as follows, expressed in tons :—

Muriate of Potash.

Country.	1896	1897	1898	1899	1900
	80 per cent.	80 per cent	80 per cent.	80 per cent.	80 per cent.
Germany ... tons	53,497.6	49,800.1	51,617.4	56,921.4	68,632.5
Austria	2,832.6	2,606.4	2,595.6	3,932.9	3,930.4
Switzerland	1,077·1	1,172.4	1,222.0	1,427.4	1,495.5
England	9,362.5	8,779.1	10,293.3	9,513.8	10,301.9
Scotland	2,854.8	3,562.3	3,187.8	4,388.5	3,333.7
France	11,674.3	15,886.3	14 870.0	15,990,9	15,072.7
Belgium and Holland...	8,639.2	9,393.3	8,723.0	8,763.1	9,580.1
Italy	3,077.2	3,463.7	3,924.3	3,520.7	4,128.3
Scandinavia and Denmark ...	1,360.0	1,295.7	1,277.4	2,935.0	1,313.9
Russia	2,284.3	772.7	2,379.2	1,935.9	1,497.4
United States of America ...	47,755.6	44,439.3	54,271.6	52,565.7	65,131.2
Brazil	128.9	52.1	—	.6	—
Spain	318.8	599.8	978.1	2,143.1	2,255.5
Portugal	100.1	72.8	143.1	20.3	62.9
Other Countries outside Europe ..	578.9	418.3	444.9	784.1	1,063.8
	145,541.9	142,314.3	155,927.7	164,843.4	187,799.8

Potash Manure Salt.

Country.	1896	1897	1898	1899	1900
	80 per cent.	80 per cent,	80 per cent.	80 per cent.	80 per cent.
Germany ... tons	621.8	736.4	807.2	—	—
Scandinavia and Denmark... ...	1,515.5	2,325.2	2,770.2	2,588.7	3,621.8
Austria-Hungary ...	—	·8	26.4	—	—
	2,137.3	3,062.4	3,603.8	2,588.7	3,621.8

Sulphate of Potash.

Country.	1896	1897	1898	1899	1900
	90 per cent.	90 per cent.	90 per cent.	90 per cent.	90 per cent.
Germany ... tons	2,653.5	843.8	679.1	1,170.4	2,608.3
Austria	5.0	16.0	—	0.1	1.6
Switzerland	10.3	11.7	20.2	12.5	21.6
England	985.0	1,499.8	1,763.4	1,704.3	1,723.7
Scotland	592.2	22.0	54.8	26.8	22.1
France	2,078.5	3,143.0	1,956.9	4,704.5	5,340.4
Belgium and Holland...	695.0	861.6	1,089.4	11,60.1	12,07.5
Italy	126.7	201.2	337.2	399.9	742.1
Spain	84.6	426.5	424.5	953.0	1,528.3
Portugal	5.1	5.1	96.2	5.0	18.1
Scandinavia and Denmark...	43.2	59.1	1.4	43.1	18.8
Russia	470.3	355.2	576.5	911.4	993.3
United States of America	5,138.3	6,605.5	9,307.6	9,744.7	13,801.4
Brazil	73.7	—	—	—	—
Other Countries outside Europe... ...	972.3	1,352.3	1,474.3	3,820.0	3,227.8
	13,888.7	15,402.8	17,781.4	24,656.8	31,255.0

Sulphate of Potash-Magnesia (calcined).

Country.	1896	1897	1898	1899	1900
	48 per cent.	48 per cent.	48 per cent.	48 per cent.	48 per cent.
Germany ... tons	231.4	173.4	136.1	64.5	43.3
Switzerland	—	5.1	—	—	—
England	263.4	412.4	351.9	315.7	455.5
France	206.4	160.7	108.5	124.4	248.2
Belgium and Holland	426.3	763.7	966.9	1,922.1	2,474.0
Scandinavia and Denmark...	2.6	—	—	—	—
United States of America	3,449.1	5,868.9	8,945.1	5,702.3	8,911.5
Brazil	1.0	—	—	—	—
Other Countries outside Europe... ...	41.8	30.6	26.8	330.0	17.6
	4,622.0	7,414.8	10,535.3	8,459.0	12,150.1

Sulphate of Potash-Magnesia (crystallised).

Country.	1896	1897	1898	1899	1900
	40 per cent.	40 per cent.	40per cent.	40 per cent.	40 per cent.
Germany ... tons	1,050.7	913.5	913.9	578.9	881.6
Other Countries ...	—	8.4	—	—	—
	1,050.7	921.9	913.9	578.9	881.6

Potash Manure Salt.

Minimum 20, 30 and 40 per cent.

Country.	1896	1897	1898	1899	1900
Germany ... tons	309.5	197.3	75.1	33,113.2	57,926.0
Austria-Hungary ...	5.0	—	—	776.5	1,481.3
Switzerland	—	—	—	—	195.5
England	106.7	264.0	333.5	899.6	958.0
Scotland	502.4	737.8	909.8	772.2	1,930.4
France	445.0	160.0	260.0	210.0	60.0
Belgium and Holland..	320.6	293.5	394.5	151.0	240.0
Spain	409.0	413.8	484.1	344.0	287.0
Scandinavia and Denmark...	—	—	22.4	10,546.8	13,610.8
Russia	—	—	—	98.8	529.0
United States of America	508.0	508.0	660.4	20,568.2	47,870.4
Other Countries outside Europe ...	—	50.0	50.0	—	0.2
	2,606.2	2,624.4	3,189.8	67,481.3	125,088.6

Kieserite (calcined).

Country.	1896	1897	1898	1899	1900
Germany ... tons	80.0	148.5	602.8	197.6	278.4
Other Countries ...	131.0	65.2	125.4	62.1	79.9
	211.0	213.7	728.2	259.7	358.3

Kieserite (in blocks).

Country.	1896	1897	1898	1899	1900
Great Britain ... tons	20,817.9	20,330.2	13,969.7	19,372.8	23,083.5
United States of America	1,779.0	2,286.0	2,819.4	3,098.8	2,133.6
Other Countries ...	2,390.5	3,052.9	3,145.3	5,744.6	32,90.4
	24,987.4	25,669.1	19,934.4	28,216.2	28,507.5

Kainite and Sylvinite.

Country.	1896	1897	1898	1899	1900
Germany ... tons	557,526.6	668,340.0	722,115.1	717,637.2	724,624.1
United States of America	135,158.7	168,869.4	176,065.2	138,874.7	176,708.3
Other Countries ...	109,900.9	126,895.7	158,045.7	175,994.5	198,299.0
	802,586.2	964,105.1	1,056,226.0	1,032,506.4	1,099,631.4

Carnallite and Rock Kieserite.

Country.	1896	1897	1898	1899	1900
Germany ... tons	56,540.7	58,543.9	60,793.1	58,677.2	55,489.3
Other Countries ...	3,963.6	5,157.2	7,188.6	4,610.7	2,868.7
	60,504.3	63,701.1	67,981.7	63,287.9	58,358.0

The **distribution** of the *muriate of potash* and the *sulphate of potash*, as raw materials, for their principal applications in industry, is shown in the following tables :—

Muriate of Potash.

A. In Germany.

For manufacture of	1896	1897	1898	1899	1900
	80 per cent.	80 per cent.	80 per cent.	80 per cent.	80 per cent.
Caustic potash... tons	32,534.2	30,603.2	3,0122.3	32,000.2	44,596.9
Nitrate of potash ...	14,912.7	12,784.4	14,334.1	18,462 6	16,078.2
Chromate of potash ...	1,127.2	1,053.3	1,206.0	1,100.3	1,167.3
Chlorates	948.8	1,040.1	763.3	862.5	627.6
Other products ...	3,239.6	3,593.8	4,471.1	4,086.3	5,734.5
Agricultural purposes	735.1	725.3	7,20.6	409.5	428.0
	53,497.6	49,800.1	51,617.4	56,921.4	68,632.5

B. In Foreign Countries.

For manufacture of	1896	1897	1898	1899	1900
	80 per cent.	80 per cent.	80 per cent.	80 per cent.	80 per cent.
Caustic potash... tons	1,101.1	119.7	579.6	49.0	626.6
Nitrate of potash ...	21,672.9	17,123.0	25,358.0	19,583.0	24,124.4
Chromate of potash ...	3,546.2	4,306.2	4,135.1	5,021.0	4,147.7
Chlorates	8,318.7	10,665.4	11,542.7	12,823.6	13,008.9
Alum	415.2	319.8	211.5	203.8	244.4
Other products ...	2,195.1	1,690.4	1,613.3	3,491.2	4,965.9
Agricultural purposes	54,795.1	58,289.7	60,870.1	66,750.4	72,049.4
	92,044.3	92,514.2	104,310.3	107,922.0	119,167.3

Sulphate of Potash.

A. In Germany.

For manufacture of	1896	1897	1898	1899	1900
	90 per cent.	90 per cent.	90 per cent.	90 per cent.	90 per cent.
Caustic potash tons	1,902.3	175.7	79.1	—	1,085.0
Alum	203.8	234.4	218.5	268.0	322.0
Other products ...	268.2	254.3	137.0	585.9	1,042.4
Agricultural purposes	279·2	179.4	244.5	316.5	158.9
	2,653.5	843.8	679.1	1,170.4	2,608.3

B. In Foreign Countries.

For manufacture of	1896	1897	1898	1899	1900
	90 per cent.	90 per cent.	90 per cent.	90 per cent.	90 per cent.
Caustic potash tons	38.4	27.4	38.4	33.0	32.8
Chromate of potash ...	493.3	15.0	240.0	40.8	124.2
Alum	1,298.4	917.5	1,159.0	837.5	1,284.0
Other products ...	157.1	108.4	126.0	1,044.4	1,024.7
Agricultural purposes	9,248.0	12,990.7	15,538.9	21,569.7	26,181.0
	11,235.2	14,559.0	17,102.3	23,485.4	28,646.7

The increase in the sale of **muriate of potash** at 80 per cent, without taking into account that of potash manures, amounted to 26,489.3 tons, distributed amongst the various countries, as follows :—

Germany	11,711.1	tons
Belgium and Holland	817.0	„
England	788.1	„
Italy	607.6	„
United States of America	12,565.5	„

whilst a decrease took place in the following countries :—

France	918.2 tons
Scotland	1,054.8 „
Scandinavia and Denmark	1,621.1 „
Russia	438.5 „

The decrease in the sale to Scotland is caused by bad management, whilst that to Scandinavia is referred to irregular management and some trouble in one of the new-built chemical works.

The market in **sulphate of potash** remained during the whole year very animated, and particularly in the autumn the demand was greater than the supply. The sale during 1899 has increased almost everywhere, viz. :—

Germany	14,379 tons
France	6,359 „
Spain...	5,753 „
Italy	3,422 „
United States of America	40,567 „

The sulphate of potash is used in Germany for technical purposes only, whilst in other countries it is used principally in agriculture.

Calcined sulphate of potash-magnesia was sold, during the year, in greater quantities than was previously estimated, consequently the greatest efforts were necessary to execute in proper time the autumn orders already in hand. Belgium and Holland received 551.9 tons, and the United States of America 3,209.2 tons more in the past year than in 1899, whilst the consumption in the tropical countries decreased. In Holland the increase has been regular for several years, but in the United States of America the consumption has varied by reason of the changeable climate. During the last year the maximum of the averaged consumption for the last six years was again reached, amounting to 8,900 tons, being still far below the consumption of 11,500 tons in 1893 and 11,800 tons in 1894.

Potash manure salts have received a greater attention during the last year, at home as well as abroad, than during the previous year 1899, the fact being that the consumption was nearly doubled; Germany, Scandinavia and the United States of America taking the leading part, whilst in Austria-Hungary, Switzerland, Scotland and Russia the consumption, although greatly increasing year by year, is far from reaching a normal quantity, these countries being in this respect far behind the foregoing.

Potash manures of minimum 38 per cent. go chiefly to Sweden, Norway and Denmark, finding there a steady market.

Kieserite, in blocks, has sold to about the same extent as during 1899, although a change has taken place in regard to locality; the demand in England, for instance, has greatly increased, whilst other countries have required less.

The business in **crude potash salts** has been normal on account of the favourable weather conditions which existed during 1900.

The increase of 67,125 tons during last year in the sales effected of kainite and sylvinite cannot be considered wholly satisfactory, particularly when it is remembered that the total amount disposed of in 1899 was less than in 1898; but in forming an opinion of the trade in the crude salts it must be borne in mind that their consumption is largely controlled by the activity of the demand for potash manures.

The above-mentioned increase was distributed amongst the following countries as follows:—

43,261.2 tons in the United States of America.
11,918.1 „ „ Belgium and Holland.
3,265.8 „ „ France.
2.822.9 „ „ Scandinavia.

whilst Germany participates with 4,200 tons only.

The total increase in the consumption of potash salts, estimated as *pure* potash, amounted during 1900 to 40,288 tons.

PRICES OF POTASH-SALTS.

The prices established by the "Potash Syndicate" for the various products differ, as we have seen, for the home and foreign markets, being considerably lower in Germany than in other countries.

Those fixed for 1900, including package free, railway station Stassfurt, and per cash, were as follows for *Germany*:—

A.—Potassium Chloride (K Cl.).

Prices per 100 kilo, in quantities of not less than 50 metric tons.

Per cent. K Cl.	Marks per 80 per cent. K Cl.	REMARKS.
	(*a*)	
80–85	14.25	1 mark = 1 Shilling.
85–88	14.35	(*a*) The prices are all based upon 80 per cent.
88–90	14.45	K Cl; the excess is charged for at different rates,
90–95	14.55	according to the exact analysis of the material.
95–96	14.75	Thus 84 per cent. K Cl would cost 14.25 marks,
96–97	14.85	plus 0.712 marks (4 per cent. K Cl at basis of
97–98	14.95	14.25 marks for 80 per cent.), or 14.962 marks.
98–100	15.15	(*b*) With not more than 0.5 per cent.
98–100 (*b*)	15.25	Na Cl.

If the salts are taken in less quantities, the prices are raised accordingly, viz. :—

Between 50 and	15 tons,	2d. more per	100	kilo	and	80 %	K.Cl.
,, 15	,, 5 ,,	4d.	,,	,,	,,	,,	
Less than	5 ,,	6d.	,,	,,	,,	,,	

B.—Potassium Sulphate ($K_2 SO_4$).

High grade, in any quantity.

For minimum of 90% $K_2 SO_4$ and maximum of 2·5% Cl.	16·45 marks per 100 kilo. net, and 90%
For minimum of 96% $K_2 SO_4$ and maximum 1% Cl.	16·85 marks per 100 kilo. net, and 90%

C.—Double Sulphate of Potassium and Magnesium ($K_2 SO_4$, $Mg SO_4$).

In any quantities.

(1) Calcined, containing a

Minimum of 48% $K_2 SO_4$ and a maximum of 2·5% Cl.	8 marks per 100 kilo. net, and 48% inclusive of sack.

(2) Crystallised, containing a

Minimum of 40% $K_2 SO_4$ and a maximum of 1% Cl.	6·40 marks per 100 kilo. net, and 40% exclusive of sack.

D.—Potash Fertilizer.

Exclusive of package in cartload lots.

For minimum of	20%	pure potash :	3·10	marks	per 100	kilo.
,,	30%	,,	4·75	,,	,,	,,
,,	40%	,,	6·40	,,	,,	,,

E.—Kieserite, Calcined and Ground ($Mg SO_4$).

In any quantity.

For a minimum of 70% $Mg SO_4$: 2·60 marks per 100 kilo., and no additional charge for an excess of that percentage.

For deliveries to other countries, the prices are fixed by the respective agents. In England, the different agents give different prices,

GERMAN

MINING

LAWS.

THE GERMAN LAWS FOR MINING OF ROCK AND POTASH SALTS.

The laws in regard to deep drilling are not uniform in the different German States. Some of the north and middle German States, notably *Anhalt*, *Mecklenburg*, *Brunswick* and *Lippe*, recognising the great agricultural and financial value of the deposits, immediately declared the rights of exploration a "State monopoly," which they afterwards transferred under large guarantees singly or to a limited number of individuals.

In *Prussia* the conditions are different for the *Provinces of Saxony and Hanover*. In the former the right of prospecting is free; the mining concession belongs to the first discoverer of the deposits, without regard to the owner of the soil surface.

In the province of *Hanover*, the mining rights belong to the owner of the soil surface, from whom a permit must be acquired before any prospecting can be done. At first this permit could be had cheaply, but now the owner demands a good price, without regard to the chances of ultimate success, and also stipulates that he shall receive a certain sum for each centner of potash and rock-salt that may be mined.

As soon as the presence of salts is assured to the satisfaction of the mining officials, the prospector can obtain the rights to a certain area of surface, amounting, in Prussia, to 2,189,000 square metres (about 500 acres). This is rather insufficient for the needs of an active mine, and the prospectors or companies aim therefore to get new concessions by drilling in adjacent areas.

APPLICATION
of
POTASH
SALTS
in
INDUSTRY.

APPLICATION OF POTASH SALTS IN INDUSTRY.

The crude potash salts are partly consumed directly or after pulverisation, while the remainder are transformed into refined and concentrated products as required by chemical industry and agriculture, such products, on account of their smaller bulk, being more suitable for transport and exportation.

Chemical works have, therefore, been established by the different mining companies, and there are also a large number of independent concerns that derive their raw materials from the mines, under a strict compact as to the manufacture and sale of the products.

The independent concerns are here given in the order of their establishment:—

Chemische Fabrik Kalk, Leopoldshall, 1861.

Chemische Fabrik Fr. Müller, Leopoldshall, 1862.

Chemische Fabrik Harburg, Stassfurt, 1870 (late Thaerl & Heidtmann).

Stassfurter Chemische Fabrik, 1871 (late Vorster, Grünberg).

Vereinigte Chemische Fabriken, Leopoldshall, 1872.

Chemische Fabrik Concordia, Leopoldshall, 1872.

Chemische Fabrik Maigatter, Green & Co., Leopoldshall, 1872.

Chemische Fabrik Beit & Co., Stassfurt, 1876 and 1881.

The most important of the various products is "Potassium Chloride" or "Muriate of Potash," which is used, moreover, as a basis for the manufacture of other potassium salts.

The principal raw material is Carnallite, or, strictly speaking, the mixture of minerals which forms the deposit so entitled (carnallite itself being present to the extent of 60 per cent.), and has an average content of 15 per cent. K Cl. The extraction of potassium chloride is based on the following facts:—

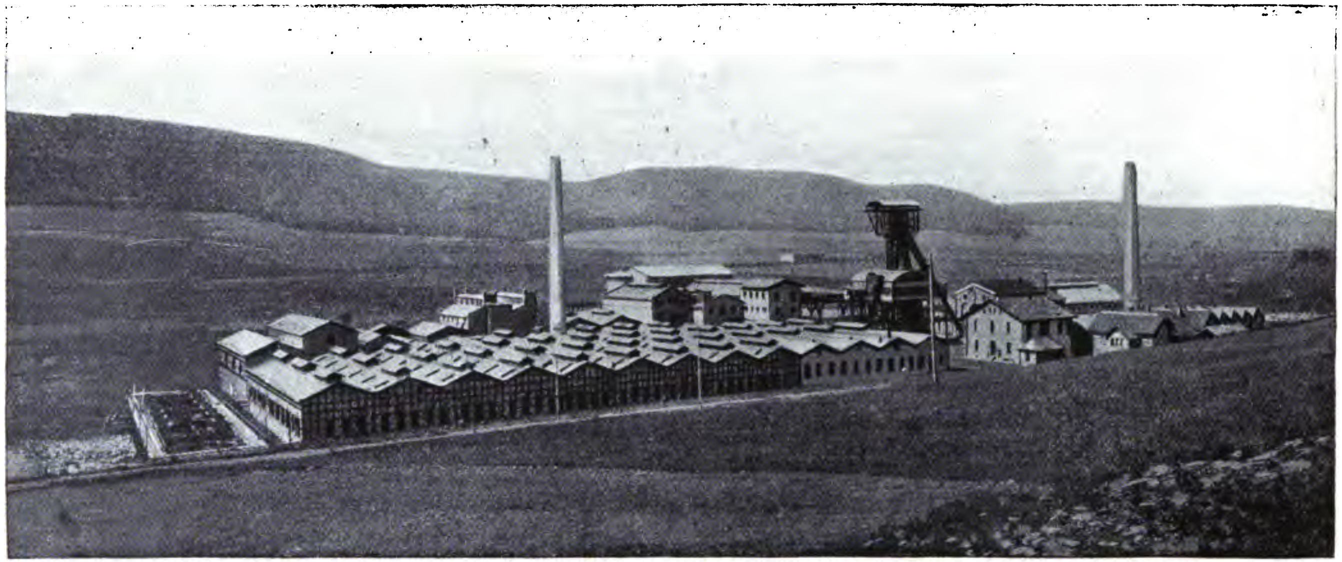
(1) Carnallite is much more soluble than the associated rock-salt and kieserite;

(2) It is decomposed by water, which forms a solution of potassium chloride, and leaves the magnesium chloride as a residue;

(3) Potassium chloride is much more soluble than sodium chloride in a saturated solution of magnesium chloride;

(4) Potassium chloride is more soluble when heated.

Fig. 15. Main View of the Potash Mines and Chlorate Works, Glückauf-Sondershausen.



It is thus easily understood, that by treating the mineral with a hot saturated solution of magnesium chloride, the potassium chloride will be dissolved, and subsequently precipitated from the solution by cooling.

In practice the operation involves many more details; the principal steps, however, are as follows:—

Roughly ground carnallite is placed in pans of a special construction and treated with a solution of chloride of magnesium, steam being passed through to aid the solution. In this way the muriate of potash in the carnallite is dissolved, and the solid residue, referred to below, consists principally of rock-salt and kieserite. When the turbidity has cleared, the solution is run into large iron crystallising tanks, and is allowed to cool for three or four days, when muriate of potash, of a strength of about 60 to 75 per cent. K Cl, crystallises out. By evaporation and subsequent cooling of the mother-liquor, still rich in potassium chloride, an artificial carnallite, $K\ Cl,\ Mg\ Cl_2,\ 6\ H_2O$, is obtained, which, after being again dissolved in hot water, on cooling, forms crystals of a specially pure muriate of potash. The product from these two crystallisations is ultimately washed with cold water, in order to remove the common salt and chloride of magnesium. After drying, the final product is a refined muriate of 70 to 99 per cent. K Cl, according to the process adopted. The residual liquor mainly consists of chloride of magnesium, which is used considerably in the English spinning mills, as added to the stiffening material (starch) used, in order to keep it moist; it contains 0·2 per cent. of bromine. From this solution the chloride of magnesium is recovered by simple evaporation, and the bromine either by treatment with chlorine or by the electrolytic process.

From the solid residue of the first solution of the carnallite the kieserite settles out from suspension in cold water in fine crystalline particles, and is moulded into blocks, giving the block-kieserite. It is sold with a guarantee of 55 per cent. sulphate of magnesia. A small quantity of kieserite is calcined and ground, and sold with a guarantee of 70 per cent. of sulphate of magnesia.

Several modifications of this method give a richer product in a shorter time, and the manufacturers at Stassfurt produce different qualities of the salt, graded from 70 to 98 per cent. K Cl.

The chloride of potassium serves as a basis for the manufacture of other potassium salts, and is employed in making a number of chemical compounds, in the preparation of saltpetre by the reaction on sodium

nitrate, for potassium chlorate and bichromate, and for alum. The 90 to 98 per cent. K Cl salts are best utilized for the manufacture of potassium carbonate.

The carnallite furnishes also the principal raw material for other products utilized in the industries and in agriculture.

Crude kainite is the source, by a somewhat complicated method of Potassium-magnesium sulphate, so largely used as a fertilizer. The product is made in two forms: crystallized, containing 42 per cent. $K_2 SO_4$ (21·6 per cent. K), and calcined, with 48 per cent. $K_2 SO_4$ (25·9 per cent. K). The latter is sold as a manure, and the greater part of the former is used in commerce for making Potassium sulphate, which is brought into the market in two qualities.

The manufacture of potassium sulphate is not so extensive as that of potassium chloride; numerous processes are used, one of the principal ones being as follows :—

The kainite is dissolved and the potassium-magnesium sulphate is recovered from the heated solution by cooling; this material is then heated with potassium chloride, which reacts upon it and forms potassium sulphate and magnesium chloride. The potassium sulphate product varies in richness from 90 to 96 per cent. $K_2 SO_4$ (approximately 40 to 48 per cent. K), and is sold mainly for agricultural purposes; a considerable amount, however, is manufactured into Potassium carbonate by the Leblanc process.

The Stassfurt works turn to account also the bye-products from the manufacture of potassium chloride, the insoluble residue from the washings, the deposits in the clarifying tanks, boilers, &c., and produce therefrom Potash manure salt, principally magnesium and sodium salts, although they may contain from 20 to 30 per cent. K as K Cl. These residues are ground, dried, calcined and enriched by the addition of crude sylvinite, or even potassium chloride. They are sold under various names for fertilizing purposes.

Attempts are being made to utilize the magnesium chloride formed in manufacturing the other salts, and at present allowed to go to waste. Small quantities have always been used as wash water in drilling, but it is probable that it will be more widely employed in the future for the preparation of such chemical substances as hydrochloric acid, chlorine, chloride of lime and ammonia, and also of bromine, of which, as we have said, there is about 0·2 per cent. The preparation of hydrochloric acid is based on the fact that $Mg Cl_2$ decomposes when heated in the

presence of steam. Chlorine and bromine may e produced by electrolytic methods, and the former placed on the market as chloride of lime.

The occurrence of nodules of Boracite within the carnallite region is also of importance to the industry, as considerable quantities of boric acid and boric salts are prepared.

An interesting fact deserving mention here is that in addition to potassium chloride, Rubidium and Cæsium are recovered in small amounts from the crude carnallite and sylvinite.

The variation in the raw material employed, and the differences in the chemical processes, make it impossible to assign a fixed composition to the products, but the appended representative analyses will serve as a guide (see next page).

Production of Concentrated Potash Salts (in Tons).

YEAR.	Muriate of Potash 80%.	Sulphate of Potash 90%.	Sulphate of Potash-Magnesia.		Potash Manure Salt.	Kieserite	
			Crystallised 40%.	Calcined 48%.		In Blocks.	Ground and Calcined.
1884	106,330	3,000	400	8,000	9,500	17,800	—
1885	104,500	4,000	450	9,000	8,400	18,500	—
1886	110,200	3,639	472	10,111	8,161	19,500	—
1887	130,000	10,528	500	6,285	8,163	24,018	—
1888	132,000	10,916	522	11,380	13,918	28,325	—
1889	131,593	7,321	671	9,215	17,285	31,824	—
1890	134,760	13,839	907	10,830	17,620	32,005	—
1891	143,488	18,981	1,053	11,400	16,045	28,559	—
1892	121,028	15,466	708	11,842	16,895	23,855	11
1893	132,529	16,361	739	12,643	17,344	24,386	105
1894	147,936	15,243	1,780	12,718	19,728	26,440	216
1895	145,027	13,403	898	8,249	19,724	25,115	142
1896	155,805	13,889	1,051	4,622	19,253	24,987	211
1897	158,863	15,403	922	7,415	23,042	25,669	214
1898	174,380	17,781	914	10,535	24,284	19,934	728
1899	180,672	24,656	579	8,459	70,916	28,216	260
1900	206,471	31,255	932	12,150	129,863	28,508	358

Two-thirds of the total production of muriate of potash and one-eighth of that of sulphate of potash, and the whole of the articificially crystallised double sulphate are used in the chemical industry, at home and abroad, for the manufacture of the various potassium compounds, of which the most important are carbonate of potash, caustic potash, nitrate, chlorate, bichromate and chromate of potash, alum, permanganate of potash, cyanide, iodide, and bromide of potassium and the yellow prussiate of potash.

Average Analysis of the principal Stassfurt Potash Salts.

NAME OF SALTS. In 100 parts are contained	Sulphate of Potash. K_2SO_4	Muriate of Potash. KCl	Sulphate of Magnesia. $MgSO_4$	Chloride of Magnesium. $MgCl_2$	Chloride of Sodium. NaCl	Sulphate of Lime. $CaSO_4$	Substances insoluble in Water.	Water.	Pure Potash K_2O. Average.	Pure Potash K_2O. Guarantee minimum.
A. Crude Salts (Natural Products)—										
1. Kainite	21.3	2.0	14.5	12.4	34.6	1.7	0.8	12.7	12.8	12.4
2. Carnallite	—	15.5	12.1	21.5	22.4	1.9	0.5	26.1	9.8	9.0
3. Rock Kieserite	—	11.8	21.5	17.2	26.7	0.8	1.3	20.7	7.5	—
4. Sylvinite	1.5	26.3	2.4	2.6	56.7	2.8	3.2	4.5	17.4	12.4
B. Concentrated Salts (Manufactured Products)—										
a. Sulphates, nearly free rom Chloride										
1. Sulphate of Potash 96%	97.2	0.3	0,7	0.4	0.2	0.3	0.2	0.7	52.7	51.8
Sulphate of Potash 90%	90.6	1.6	2.7	1.0	1.2	0.4	0.3	2.2	49.9	48.6
2. Sulphate of Potash-Magnesia ...	50.4	—	34.0	—	2.5	0.9	0.6	11.6	27.2	25.9
b. Salts containing Chloride										
3. Muriate of Potash 90/95%... ...	—	91.7	0.2	0.2	7.1	—	0.2	0.6	57.9	56.8
Muriate of Potash 80/85%... ...	—	83.5	0.4	0.3	14.5	—	0.2	1.1	52.7	50.5
Muriate of Potash 70/75%... ...	1.7	72.5	0.8	0.6	21.2	0.2	0.5	2.5	46.7	44.1
4. Potash Manure Salts, minimum 20% Potash	2.0	31.6	10.6	5.3	40.2	2.1	4.0	4.2	21.0	20.0
5. Potash Manure Salts, minimum 30% Potash	1.2	47.6	9.4	4.8	26.2	2.2	3.5	5.1	30.6	30.0

In the many-sided technical and industrial activity of the twentieth century, there is scarcely a trade which can dispense with potash salts. They are used to a large extent as necessities or aids by doctors, photographers, painters, dyers, cleaners, bleachers, weavers, soap makers, electricians, also in the production of artificial cold, preservatives, fireworks, gunpowder, matches, paper, glass, aniline dyes, and in the extraction of gold from its ores, with a large number of other applications too numerous to mention.

In referring to the *methods* now employed in the manufacturing treatment of crude potash-salts, we may remark that at the works first established by Frank in 1861, he made use of the principle that from hot saturated solution of carnallite ($K Cl$, $Mg Cl_2$, $6 H_2O$) potassium chloride crystallises out on cooling, while the magnesium chloride remains in solution.

The ordinary "chemical process," used for the manufacture of potassium chlorate, is based upon the reactions (first discovered by Liebig) which occur when chlorine gas acts upon a hydrate of the alkali metals, or upon hydrates of the alkaline earths, dissolved or suspended in boiling water. Slaked lime is adopted now commercially. Five-sixths of the chlorine taking part in this reaction forms chloride, and only one-sixth is converted into chlorate. Were potassium or sodium hydrate used, over 80 per cent. would thus be converted into the corresponding chloride, and the re-conversion into hydrate would be both troublesome and costly. By using calcium hydrate, calcium chloride and chlorate are obtained in the first stage of manufacture. In order to produce the potassium salt from the impure calcium chlorate, it is simply necessary to dissolve in the hot liquor the requisite amount of potassium chloride, when potassium chlorate will crystallize on cooling; the bye-product, calcium chloride, not being saleable, is permitted to run to waste. The Liebig process is still being worked at Widnes and at St. Helens, England, and at two places in France. An electrolytic process, patented by Hargreaves, is in operation at works in Cheshire. These five factories account for about one-third of the total production of chlorates.

The Leblanc process is used in the preparation of carbonate of potash, but in certain places the magnesia process, invented by Engel, has been worked. Caustic potash is still prepared by the Leblanc method, but lately an electrolytic process is gaining ground, in which porous diaphragms and a mercury electrode are used. In both methods

chlorine is also manufactured and is utilised in the preparation of chloride of lime.

As to electrolysis, which, as we have said is steadily advancing, *Dr. Joseph Wilson Swan, F.R.S.*, in his presidential address to the Society of Chemical Industry, delivered at the annual meeting held at the University, Glasgow, July 24th, 1901, gave an exhaustive and interesting review of the subject, the following being extracts :—

The history of electro-chemistry began at the birth of the century, heralded by Volta's great discovery. The idea of the correlation of electricity and the energy that determines chemical action was then, for the first time, grasped ; and the prescience of great minds, like that of Davy, led even to an anticipation of that then far distant result, the utilization of electricity as an operative force in chemical industry. In the Bakerian lecture of 1806, Davy says: "It is not improbable that the electric decomposition of neutral salts, in different cases, may admit of economical uses." But much had to be done before industrial electro-chemistry was possible.

Electro-chemical industry depends on the production of chemical effects in a new way ; sometimes the effects themselves are new, and not otherwise producible, and in other cases the results are merely improvements on old chemical methods, either in respect of economy or superiority of the product, or both.

Sodium.—The sodium industry affords an instance of the displacement of an old and purely chemical process by an electrolytic one. The change has been brought about on the sole ground of the greater economy of the electrolytic method.

The principle of Castner's sodium process is exactly like Davy's—both are electrolytic, and in both the electrolyte is fused sodium hydrate. The apparatus, as patented, is simple. An iron pan, with a fire under it, contains the fused sodium hydrate. The cathode passes up into this vessel through an opening in its base, and both it and the annular anode, which surrounds its upper portion, are formed of nickel. A strong current is employed, which helps to keep up the temperature of the electrolyte to fusion point. The sodium is released, as liquid metal, and rises to the surface of the fused soda, means being taken to remove it and to prevent its combustion on coming in contact with the air.

By this process sodium is now manufactured by hundreds of tons, and passes into commerce partly in metallic form, chiefly for the use in the cyanide manufacture, but a considerable portion is converted into peroxide of sodium. The output in 1897 was 260 tons.

The Castner sodium process is operated at Western Point, at Rheinfelden and at Niagara. Electrolytic processes are also in use at Bellegarde, at Bitterfeld, at Höchst O/M, near Frankfort, and at Neuhausen. Further details will be found in the following table :—

Sodium Extraction Works in Europe, 1900-1901.

Name of Firm,	Locality of Works.	Source of Power.	Horse Power.		Output in 1900.
			Available.	Utilised.	
Elektro-Chemische Werke	Bitterfeld ...	Steam	3,000	?	?
Castner-Kellner Alkali Company	Western Point	Steam	4,000	?	?
Elektro Fabrik Natrium ...	Rheinfelden	Water	?	?	?

In addition to the above, one or two of the German colour works are producing sodium by the electrolytic method for their own requirements.

Magnesium. — In the extraction of magnesium, also, the electrolytic method has superseded the chemical process. The method is analogous to that used for the extraction of sodium. The electrolyte is fused carnallite. The magnesium industry is small, no large use for the metal having yet been found, and the only factory is that at Hemelingen, in Germany. Quite lately a promising alloy of aluminium and magnesium (called "Magnalium"), said to have excellent qualities, has been attracting attention.

The Alkali and Chlorine Industry.—The electrolytic alkali and chlorine industry embraces the production of caustic and carbonated alkali, and of bleaching powder, hypochlorites and chlorates.

For obtaining chlorine and sodium, or chlorine and soda, no process can, theoretically considered, be more beautifully simple and complete than the electrolysis of chloride of sodium. But when an attempt is made to carry out this form of decomposition on an industrial scale, a number of perplexing practical difficulties present themselves.

If, with a view to obtain a high yield from a small plant, the chloride is used in the state of fusion, then the selection of a suitable material for the electrolytic cell, and the separation of the electrolytic products, both at a high temperature, are found to be matters of serious difficulty.

Numerous attempts have nevertheless been made to overcome these obstacles, and two processes, namely, that of Hulin and that of

Acker, have attained industrial trial in France and America respectively.

The Hulin system has not achieved financial success, and is being modified in several respects. The Acker process, using metallic lead is more recent, and, though now in operation at Niagara, its ultimate value is uncertain.

Greater success has attended the employment of aqueous solutions of common salt as the electrolyte, for the production of alkalies and bleach. The electrolytic decomposition of brine, or of potassium chloride solutions, has already attained the rank of a stable and successful industry. The forms of apparatus employed have not yet settled down to a uniformity of type, such as obtains in the competing chemical processes ; and there is much obscurity concerning details of the work at several of the continental factories.

It may, however, be stated that there are two well-marked types of cell employed in the electrolysis of brine for production of alkalies and chlorine. One is the form in which mercury serves to amalgamate with and separate the sodium or potassium set free at the cathode, and to remove it from the area of electrolytic or chemical reactions within the primary cell. In the other type of cell a diaphragm divides the anode and cathode compartments, so that the chemical reactions by which the metal is transformed into the hydrate and the chlorine is liberated, are as far as possible kept separate.

With respect to the first cell two forms are in actual use with satisfactory results, namely, the Castner-Kellner and the Solvay cells. The former is in use, as we have seen, at Western Point, at Ostenienberg and at Niagara ; while the latter is said to be working at Jeneppe, in Belgium, and at Donetz, in Russia. The process of the Elektron Company, of Frankfort, now carried out at various alkali works in Germany, France, Switzerland and Russia, is stated to include the use of diaphragms.

The cleanliness and regular working of an electrolytic alkali process are important points in its favour.

In regard to the industrial position of the diaphragm cell, three modifications of it are in practical operation, one of the best known being that of Hargreaves and Bird. The success of an experimental paint, which was worked for six years at Farnworth, has led to the erection of a large factory at Middlewich, in Cheshire. In the cell room there is now working one unit, or 56 cells, 12 out of each 14

of which are always in operation at one time, the remaining two being held in reserve, each cell taking an E.M.F. of nearly 5 volts, and a current of 2,000 to 3,000 amperes. The works are under extension.

The higher E.M.F. required by this cell than that given by Mr. Hargreaves, is stated to be due to the use of thicker diaphragms. The product here is not caustic, but carbonate of soda, with bleaching powder.

Asbestos and Portland cement, rendered porous by the admixture of various salts during setting and subsequent lixiviation, have both been successfully employed as the material for the diaphragms.

Other diaphragm processes in actual operation are the Outhenin-Chalandre and the Le Sueur patents. The first is worked at Chèvres, near Geneva, and at Montiers, in France; the second at a paper mill near Berlin Falls, New York.

The Outhenin-Chalandre cell consists of a bell-shaped anode-chamber of suitable material, into the sides of which a large number of porous tubes are fixed, in a position slightly inclined from the horizontal. These tubes act as diaphragms, and contain the sheet-iron cathodes. The caustic soda solution, formed at the cathodes, passes to the lower ends of the tubes, and then collects at the bottom of the cell by gravity.

The Le Sueur cell contains a horizontal diaphragm, with the anode compartment on the upper side. The diaphragms are said to be of asbestos, and last from three to six weeks. Each cell takes 800 amperes at six volts, and has a current efficiency of 70 to 80 per cent.

Although the principle of cell construction in which gravity is relied on for the separation of the sodium hydrate formed at the cathode, and in which, therefore, a diaphragm or mercury is dispensed with, has been discredited by the failure of the Richardson and Holland process at St. Helens, yet a cell on that principle seems to be working with satisfactory results at Aussig, producing alkalies and bleach at the rate of 2,640 tons per annum.

A recent laboratory research by Adolph has shown that, under careful regulated conditions, a current efficiency of over 80 per cent. can be attained in these cells with continuous work; and as the saving in cell construction and E.M.F. is considerable, it is possible that "gravity" cells may once again come into use.

There are now 23 electrolytic alkali works in operation in Europe, disposing in the aggregate of 50,000 horse-power. All the attainable details are presented in the following table :—

Alkali and Bleach Works in Operation in Europe 1900–1901.

NAME OF FIRM	Locality	Source of Power	Horse-power		Output in 1900 in Tons
			Available	Utilised	
Bosnische Elektricitäts Aktiengesellschaft	Jajce	water	9,200	—	—
The Castner Kellner Alkali Co.	Western Point	steam	4,000	—	—
Elektro-Chemische Werke	Rheinfelden	water	3.500	—	—
"	Bitterfeld	steam	3,000	—	—
Société des Soudières Électrolytiques	Les Clavaux	water	2,600	at present stopped.	—
Soc, Italiana di Elettrochimica " Volta "	Bussi	water	2,800	under construction.	—
Societa Anonyma Elektra del Besaya	Barcena	water	2,400	under construction.	—
Solvay et Cie	Jemeppe	steam	1,500	1,000	caustic, 630 bleach, 1,360
Deutsche Solvay Werke	Osternienberg	steam	1,500	1,000	caustic, 1,535 bleach, 3,338
Lubimoff, Solvay et Cie	Donetz	steam	1,500	under construction	—
Soc. des Usines de Produits Chimiques de Monthey	Monthey	water	1,500	680	caustic, 1,000 bleach, 2,500
Akcyjne Towarzystons " Elektryczuon "	Zombkowice	steam	1,200	1,200	caustic, 1,250 bleach, 2.550
Soc. Anonyme Suisse de l'Industrie Électrochimique " Volta " ...	Chèvres	water	1,000	500	caustic, 600
The Electrolytic Alkali Co.	Middlewich	steam	1,000	—	bleach, 1,440

The above 14 works have available 13,700 horse power (steam) and 23,000 horse power (water); total, 36,700 horse power. The output of six works in 1900 was 12,000 tons of caustic soda and 26,000 tons of bleaching powder. Nine works have failed to send any figures.

Hypochlorites.—As regards the production of hypochlorites there are a very large number of firms in Europe using electrolysis for production of bleaching solutions containing sodium hypochlorite. The cells are patented under various names and differ in details of construction, but the principle of the method employed is common to all, and depends upon the chemical action that takes place when chlorine gas is passed into a solution of sodium hydrate at a temperature below 20° C. The solution obtained may contain up to 10 grammes available chlorine per litre. Bleaching liquids, prepared in this way, are being utilised in the textile and wood-pulp industries of the Continent to an increasing extent. The works are often on a somewhat small scale, and it is impossible to obtain complete details, but 1,600 horse-power is reported to be used in Southern Germany by one form of apparatus alone, so that the aggregate power utilised by the six different types should be considerable. One of the most notable installations of this kind is at Lancy, Isere, France, where Messrs. Corbin & Cie are employing 700 horse-power for the bleaching of cellulose, using their own form of apparatus and cell. The Kellner-Partington Paper Pulp Company have also a large installation at Sarpsfors in Norway.

Chlorates.—The production of chlorates by the electrolysis of solutions of potassium or sodium chloride is one of the older electro-chemical industries, Gall & Montlaur having commenced this manufacture on a limited scale at Villers-sur-Hermes in France in 1899, and with a much larger plant at Vallorbe, in Switzerland, in 1890.

Cells of five different species are now in use for the preparation of electrolytic chlorates; but, as in the case of hypochlorites, the principle underlying all is the same, the differences consisting simply in details of cell construction. Diaphragms are still employed in the original process of Gall & Montlaur, but elsewhere this feature appears to have been abandoned.

The Kellner method according to the description of works at Golling, is similar in general character to that of Gall & Montlaur and of the Corbin Co.; but special forms of anode are used, and a small percentage of calcium hydrate is added to the salt-solution contained in the cell. The addition is supposed to lessen the loss by reduction at the cathode, and thus to increase the efficiency.

The Carlsen process and cell (Swedish Patent No. 3,614 of 1890) is said to be in use on a large scale at Mansboe, Sweden, and, according to Dr. F. Peters, is likely to invalidate many of the later patents.

It has been more than once remarked that Charles Watt, the pioneer in all electrolytic processes for the decomposition of salt solutions, in British Patent No. 13,755 of 1851, clearly forestalled all later inventors as regards the chief features of the process and cell for chlorate production, and it is doubtless a knowledge of this fact that renders the owners of more recent chlorate patents somewhat chary about enforcing their claims as to supposed infringement.

The Hargreaves chlorate process at Messrs. Bowman, Thompson & Co.'s works in England, and at the St. Gobain works, near Paris, is only partially electrolytic, and is, in fact, merely an improvement in effecting the chemical reaction between the chlorine and the sodium salt, in which the former may be produced either by electrolysis, or chemically from hydrochloric acid. By the older method of manufacturing sodium chlorate, great loss occurs on crystallization, owing to the excessive solubility of the salt, and Hargreaves has sought to avoid this inconvenience by allowing the chlorine to act on semi-dry sodium carbonate in a tower, and so regulating the supply of steam, that only the more soluble sodium chlorate should be dissolved. For potassium chlorate production the method is less advantageous, since the potassium salt is much less soluble, and its separation from the mother liquors, by crystallization, is attended by less serious loss.

The number of works producing chlorates by the electrolytic method is now ten, seven of these being in Europe, and 28,000 horse-power is available for this manufacture.

The prices of chlorate have fallen greatly since the electrolytic process was adopted on a large scale. Whereas, ten years ago, chlorate of potash was selling at 6d. per lb., it is now quoted at only 3½d. The manufacture having become less remunerative, some of the factories are being used for other products.

The following table gives all the available information, relative to power and output, in condensed form.

Chlorate Works in Operation in Europe, 1900–1901.

NAME OF FIRM.	Locality.	Source of Power.	Horse-Power.		Output in 1900 in Tons.
			Avilable.	Utilised.	
Corbin et Cie....	Chedde	Water	12,000	9,000	4,500
Société d'Électro-Chimie ..	St. Michel de Maurienne	"	4,000	?	—
Do. ...	Vallorbe	"	3,000	?	—
Superfosfat Fabriks Aktiebolag	Mansboe	"	4.600	?	—
Do.	Alby	"	?	?	—
Consortium f. Elektrochem. Industrie	Golling	"	4,500	?	—
Gesellschaft f. Elektrochem. Industrie	Turgi	"	800	600	—

Only three of the above firms supplied the desired figures. In the remaining cases the details of the power available have been obtained from other sources.

The above seven works have over 28,000 horse-power available for the production of chlorates, and their output in 1900 is estimated to have been about 9,000 tons.

The manufacture of ammonium persulphate and perchlorate has now become a sub-branch of the electrolytic chlorate industry, and it has been stated that these chemicals are being produced by Messrs. Corbin & Co., at Chedde, and by the Swedish company at Mansboe.

In this case electrolysis has given a convenient method for producing compounds of high oxygen value on a commercial scale. They are used in photography and in the manufacture of some of the modern high explosives.

Theory.—The results of several important investigations, relating to the theory of the electrolytic chlorate cell, have been published, and are summarised by Mr. Kershaw in his "Manufacture of Potassium Chlorate," as follows :—

It is interesting to note that Schuckert & Co. have patented the addition of alkaline bicarbonates to the chlorate cell, and that Kellner has patented a similar addition of calcium hydrate. In view of Oettel's published results, it is questionable whether these patents are valid. These improvements of the original process are intended to be worked in a cell without a diaphragm, but Waubel has stated that by use of a diaphragm and of an anode solution of sodium bicarbonate, the whole of

the chloride carried into the anode chamber can be converted into chlorate. The electrolyte should be kept at 60-70°C, the current density should be 5 to 10 amperes per square meter, and the E.M.F. should be 4 to 5 volts. The solutions of bicarbonate for the anode chamber, and of chloride for the cathode chamber, should be saturated. In order to maintain the former in this state, additions of fresh amounts of bicarbonate are necessary from time to time. In the anode chamber 6·5 gramme of chlorate are obtained for every 7·5 gramme of bicarbonate used, while in the cathode chamber a 10 per cent. solution of sodium hydrate can be obtained.

Comparing the electrical energy necessary to produce chlorate by this process with that required in the experiments of Oettel and of Gall and Montlaur, the following comparative figures are obtained for the production of 88.14 gramme potassium chlorate :—

OETTEL.—Alkaline electrolyte, without a diaphragm, 1003 Watt hours.

WAUBEL.—Bicarbonate in anode chamber, with a diaphragm, 951 Watt hours.

The latter process has the advantages over the other two, that sodium hydrate is concurrently produced, and can be recovered from the cathode solution.

Müller, in a contribution published still more recently, has recorded the results of an investigation which opens the door to still more striking improvement in the efficiency of the electrolytic chlorate process. He says that the addition of a small amount of a chromate salt to the electrolyte enables a very high current efficiency to be obtained, without the use of diaphragms between anode and cathode compartments of the cell. Full details are given of the electrolytic apparatus used in these experiments, and of the chemical methods used for determining the electrical efficiency of the process.

The following figures were obtained in experiments, each of which lasted 21 hours :—

Sodium chlorate, current efficiency, 67·9 per cent.

Potassium iodate, current efficiency, 97·0 per cent.

Potassium bromate, current efficiency, 89·8 per cent.

It was found that platinum formed the best anode material.

He concludes by presenting two theories to account for the remarkable action of the chromium salt, in accelerating the oxidation of the electrolyte. According to the one, a thin film of chromic hydrate is

formed over the surface of the cathode, and acts as a diaphragm to protect the oxygen salts in solution from the reducing action of the hydrogen liberated at the true surface of the cathode. According to the second, a film of an alloy of chromium and platinum forms upon the surface of the cathode and acts in a similar manner. It was found that chromates gave better results than any other oxygen salts, and that manganates have little or no effect in accelerating oxidation of the electrolyte.

Professor Foerster, in an address delivered before the sixth annual meeting of the German Society of Electro-Chemists, has given a very useful summary of the investigations carried out by Oettel, Wohlwill, Winteler, Müller and himself in relation to the electrolytic decomposition of chloride solutions, coming to the conclusion that the conditions, which the latest researches had shown to be the most favourable for the production of chlorate in the cell, were as follows :—

(1) Presence of calcium hydrate or chromium hydrate at the cathode.

(2) A slightly acid electrolyte.

(3) A large volume of electrolyte in rapid circulation.

(4) A temperature of at least 40° C.

Professor Foerster also stated that the ideal electrolytic chlorate process would be one in which pure calcium chloride was used, in place of the sodium or potassium salt. With such an electrolyte a current efficiency of 87 per cent. can be obtained.

The importance of these researches, relating to the chemistry of the electrolytic cell, annot be too much emphasised. The current efficiency of the electrolytic chlorate process, as originally carried out, was only 35 per cent., and the energy efficiency only 18 per cent. ; and as the cost of electrical energy represents a very large proportion (30 per cent.) of the total cost of production, there is evidently a wide margin for effecting improvements in the process and reduction in its cost.

Accidents.—The year 1899 was marked by a most disastrous explosion at one of the English chlorate factories, owned by the United Alkali Company, and, as a result of the official investigation into the cause of this explosion, a previously overlooked property of potassium chlorate has been brought to light. The experts, who have prepared the official report, have arrived at the opinion that chlorate, when subjected to intense heat, liberates its oxygen with explosive violence, and they attribute the St. Helens disaster to such an explosion of about five tons

of the chlorate, this explosion being produced by the rapid and intense heating of the chlorate in the storehouse.

The litigation between the public authorities and the United Alkali Company, with reference to claims for damages, has resulted in a verdict against the chemical company. This judgment should cause much greater care to be exercised in the manufacture of chlorates, and will lead to the use of iron in place of wood in all buildings intended for their manufacture and storage.

Packing.—The greater portion of the chlorate sold is packed as crystals; but for many uses it is necessary to have it in the form of powder. Grinding chlorate is considered the most dangerous of the operations involved in chlorate production, and a trustworthy and cool-headed man is required for the work. The crystals and powder have also to be carefully packed. In the past, small wooden barrels, lined with paper, each holding 1cwt., have been employed, but, owing to further appreciation of the explosive properties of chlorate under certain conditions, it is probable that wood and paper will no longer be used for this purpose.

On account of the readiness of cotton and wool fabrics, impregnated with chlorate dust, to catch fire and burn with explosive rapidity, the workers in the refining and grinding departments of a chlorate factory are compelled to wear special clothing, and strict rules with regard to matches and smoking are necessary. It is also advisable to have in each of the buildings large tanks of water, constantly filled, so that in case of their clothing becoming ignited, the men can put out the flames by simply stepping bodily into these tanks.

STATISTICS.

By the kind permission of Dr. Joseph Struthers, editor of "The Mineral Industry," New York, we are enabled to print the following particulars of the potash trade as issued in recent volumes of that useful publication.

Total Production, Value, Number of Works and Men employed therein, of the Crude and Manufactured Potash Salts in Germany, 1887-1897. Metric Tons.

	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897
A—Mineral Salts.										
1. *Rock Salt.*										
Output of crude marketable products (*a*)...	414,557	544,591	557,060	666,793	662,577	669,043	734,939	686,940	758,867	763,412
Value per ton in marks	4.64	4.44	4.74	5.01	5.09	5.32	5.23	5.51	5.06	4.96
Number of producing works	14	16	17	17	17	16	16	16	16	16
Average number of men employed daily ...	752	791	1,057	944	866	919	775	900	929	905
2. *Kainite.*										
Output of crude marketable products (*a*)...	318,576	324,476	361,327	472,256	548,445	616,755	726,524	680,174	877,885	992,389
Value per ton in marks	15.19	15.35	14.86	14.70	14.31	14.62	14.28	14.14	15.11	14.05
Number of producing works	6	6	6	7	5	8	8	9	9	10
Average number of men employed daily...	(*b*)	(*b*)	(*b*)	(*b*)	350	325	376	472	1,006	1,938
3. *Other Potash Salts.*										
Output of crude marketable products (*a*)...	916,759	861,273	913,030	898,992	802,630	879,477	917,049	841,748	902,107	953,798
Value per ton in marks	13.63	15.52	16.05	12.37	12.64	11.94	12.41	13.77	12.60	12.91
Number of producing works	8	10	10	11	11	13	13	13	13	16
Average number of men employed daily...	5,475	5,413	5,556	5,955	5,265	5,840	6,418	6,263	5,910	6,642
4. *Bitter Salts (Kieserite, Glauber Salt, etc.)*										
Output of crude marketable products (*a*)...	13,269	10,951	8,030	7,454	10,207	8,818	8,252	7,328	2,350	2,601
Value per ton in marks	7.90	7.76	8.69	8.75	8.76	7.74	8.72	8.11	8.86	8.67
Number of producing works	3	5	5	4	5	6	5	5	5	7
Average number of men employed daily (*c*)	—	—	—	—	—	—	—	—	—	—
5. *Boracite.*										
Output of crude marketable products (*a*)...	180	121	182	177	179	162	176	162	184	198
Value per ton in marks	319.57	299.85	301.42	285.38	303.58	287.36	251.99	236.82	232.35	209.30
Number of producing works	7	7	7	7	6	7	6	6	7	6
Average number of men employed daily ...	—	—	—	—	—	—	—	—	—	—

Total Production, Value, etc.—*Continued.*

	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897
B—Salts obtained from aqueous solutions										
1. *Table Salt.*										
Output of crude marketable products (*a*) ...	496,388	492,522	492,584	503,386	504,687	504,523	522,590	525,396	547,486	543,272
Value per ton in marks (*d*)...	21.48	24.32	26.97	26.66	27.43	27.50	27.36	27.13	26.76	22.34
Number of producing works	76	80	80	79	78	79	81	81	82	81
Average number of men employed daily ...	3,345	3,305	3,303	3,301	3,320	3,263	3,179	3,288	3,328	3,336
2. *Potassium Chloride.*										
Output of crude marketable products (*a*)...	142,765	133,957	137,005	129,512	123,962	137,216	149,775	154,427	174,515	168,601
Value per ton in marks	128.61	125.34	129.45	132.26	132.51	126.12	126.11	127.47	131.07	137.25
Number of producing works	26	25	25	25	25	25	25	26	24	23
Average number of men employed daily ...	2,559	2,448	2,652	2,470	2,384	2,526	2,399	2,481	2,455	2,371
3. *Magnesium Chloride.*										
Output of crude marketable products (*a*)...	16,643	16,728	14,958	15,619	14,386	12,764	17,422	17,039	17,525	18,014
Value per ton in marks	11.03	10.56	10.02	10.12	14.13	13.93	11.69	12.41	13.10	14.28
Number of producing works	6	5	5	4	9	9	5	5	6	6
Average number of men employed daily ...	(*e*)	(*e*)	(*e*)	(*e*)	(*e*)	(*e*)	(*c*)	(*e*)	(*e*)	(*e*)
4. *Alkaline Sulphates.*										
a. Glauber Salt.										
Output of crude marketable products (*a*)...	52,203	69,101	68,716	79,983	74,184	77,145	71,929	71,411	71,958	68,882
Value per ton in marks	25.52	24.02	25.31	25.72	27.19	25.85	23.59	22.79	24.95	25.27
Number of producing works	29	29	28	29	29	28	27	26	26	24
Average number of men employed daily...	175	279	336	315	213	213	200	249	267	278
b. Potassium Sulphates.										
Output of crude marketable products (*a*)...	33,412	29,709	31,126	37,674	26,268	27,308	23,281	19,452	19,682	13,774
Value per ton in marks	148.84	165.81	158.46	160.79	163.26	164.03	164.73	165.56	165.30	164.29
Number of producing works	13	12	11	12	12	12	9	11	10	10
Average number of men employed daily ...	77	68	42	41	49	52	47	47	8	6

Total Production, Value, etc.—*Continued.*

	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897
c. Magnesium Potassium Sulphate.										
Output of crude marketable products (*a*) ...	11,478	16,325	11,094	10,508	11,593	14,199	14,156	9,877	4,623	7,812
Value per ton in marks	79.51	79.07	77.39	75.81	78.73	79.10	77.62	78.54	74.40	76.33
Number of producing works	7	9	9	8	7	5	6	8	7	4
Average number of men employed daily(*f*)	—	—	—	—	—	—	—	—	—	—
5. Magnesium Sulphate.										
Output of crude marketable products ...	25,110	26,978	26,376	23,126	23,879	27,520	28,628	26,028	27,161	35,072
Value per ton in marks	11.34	12.99	12.10	12.30	14.07	11.51	12.41	16.47	15.88	17.74
Number of producing works	16	17	15	16	17	16	16	17	17	16
Average number of men employed daily...	—	—	—	—	—	—	—	—	—	—

(*a*) From this amount of total output of crude marketable products should be deducted a certain portion that is dissolved, boiled or given away for the manufacture of refined salts. For the actual amounts of rock salt, kainite and "other potassium salts" that appeared in the market, reference should be made to the "table of production" on page 95
(*b*) Included in "other potassium salts."
(*c*) Included in kainite and "other potassium salts."
(*d*) The values of salts obtained from aqueous solutions are given exclusive of duty.
(*e*) Included in "potassium chloride" and "potassium sulphate."
(*f*) Included in "potassium chloride."
(*g*) Included in "other potassium salts."

From the above tables it is evident that the labour employed—

In mining the crude salts in Germany was in

1875 ... 1,935 men

1897 ... 9,485 men, an increase of 7,550 men, equal to 390%

In the manufacture of salts from aqueous solutions,

1875 ... 3,696 men

1897 ... 3,975 men, or an increase of 279 men, equal to 7.5%

Labour employed in the German Salt Mines during 1890—1899.

(b)	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899
Underground Mines—										
Number of workmen ...	2,344	2,295	1,912	1,854	2,000	1,882	1,718	1,935	2,131	2,155
Number of shifts worked per man ...	294	294	303	299	292	281	302	301	302	300
Wages earned per shift, in marks (a) ...	3.48	3.63	3.81	3.69	3.65	3.56	3.65	3.81	3.81	3.85
Other Underground Labour—										
Number of workmen ...	185	170	198	658	769	704	636	736	821	855
Number of shifts worked per man ...	307	308	306	302	297	289	303	305	306	302
Wages earned per shift, in marks ...	3.47	3.59	3.47	3.30	3.19	3.26	3.34	3.40	3.43	3.58
Workmen above ground—										
Number of workmen ...	1,032	1,097	1,091	1,193	1,129	1,133	1,163	1,233	1,338	1,418
Number of shifts worked per man ...	315	312	312	305	306	298	305	306	307	307
Wages earned per shift, in marks (a) ...	3.24	3.35	3.35	3.33	3.38	3.38	3.43	3.49	3.50	3.50
Boys—										
Number of boys ...	68	90	88	86	77	60	57	81	101	105
Number of shifts worked per boy ...	311	302	298	298	296	287	300	300	301	298
Wages earned per shift, in marks ...	1.26	1.25	1.32	1.24	1.21	1.25	1.17	1.20	1.21	1.28

(a) After deducting all fees. (b) For Prussia only.

The above table shows the number of workmen employed in the Prussian salt mines to be in 1890, 3,561 men, and in 1899, 4,428 men, equal to an increase of over 27%;

whilst their average wages amounted to in 1890, 3.40 marks, and in 1899, 3.64 marks, equal to an increase of over 7%.

Number of Officials employed in the Prussian Salt Mines and their Wages.

	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899
Number of Officials	118	121	124	130	136	131	128	141	157	163
Salary per Official in marks	1,759	1,816	1,796	1,893	1,812	1,799	1,828	1,831	1,884	1,933

From the above table it will be seen that the number of officials increased from 118 in 1890 to 163 in 1899, or 38.1%. The average salary during the same time rose from 1,759 marks in 1890 to 1,933 marks in 1899, corresponding to 9.9%.

With 4,533 hands employed in the Prussian salt mines in 1899, there was an average of 28 men to one official.

Miners' Work.

The average of the miners' work has not been published for Germany or Prussia, but the following table was made up from the largest Prussian State mine in Stassfurt, and these statistics, while they do not hold good for all circumstances of the same items in salt mining and cannot always be taken as a standard, yet may be regarded as a fair representation of work that is carried out in German salt mines.

		Rock Salt.					Potassium Salts.				
		1875	1880	1890	1895	1897	1875	1880	1890	1895	1897
Average output of one miner proper per shift of 8 hours (metric tons)	Strike	—	3.45	7.35	17.29	19.927	5.15	4.50	8.57	21.24	23.99
	Overhead Stope...	27.35	15.10	27.58			29.85	28.85	28.50		
Output of one underground workman per shift of 8 hours (metric tons)		3.10	2.90	4.20	3.50	2.60	2.80	2.25	2.47	3.26	3.06
Wages per shift of 8 hours in marks	One Miner proper... ...	3.88	3.51	4.38	4.73	4.95	3.88	3.61	4.21	4.65	4.85
	One Trammer	2.75	2.61	3.47	4.33	4.29	3.00	2.48	3.36	4.28	4.16
	Altogether	2.80	2.94	3.71	3.84	3 88	2.80	2.93	3.60	3.76	3.82

Statistics for the average work in the salt works (*salinen*) and chemical manufactories have not been published as yet. The figures compiled from the largest salt works of the Prussian State at Schoenebeck, from 1875 to 1882, are given in the following table :—

Average Annual Production per Man.

YEAR.	1875	1876	1877	1878	1879	1880	1881	1882
Metric Tons	142.7	133.15	350.70	332.40	350.15	365.17	371.52	386.50

Number of Men employed by the Kali-Syndicate.

	1890	1891	1892	1893	1894	1895	1896	1897	1898
Rock Salt	—	1,355	1,985	788	1,333	1,092	1,121	1,251	1,530
Potassium Salt	6,766	6,819	6,074	7,624	10,800	9,700	10,683	10,909	12,358
Total	6,766	8,174	8,059	8,412	12,183	10,792	11,804	12,160	13,888

Accidents.—In the Prussian salt mining industry during 1899 three men were fatally wounded underground and two on the surface, making a total of five men, which, with a total force of 4,533 men employed during that year, gives a proportion of 1.1 fatality per 1,000.

APPLICATION
of
POTASH
SALTS
in
AGRICULTURE.

APPLICATION OF POTASH SALTS IN AGRICULTURE.

All plants composing ordinary farm crops, equally with animals require food for their growth and development, and the extent of productiveness depends upon the amount of the food which the plants are able to assimilate.

The food of crops is obtained from two sources, air and soil. From the air all green plants take in, by means of their leaves, carbonic acid gas, from which is derived the carbon of the organic compounds which constitute the great bulk of their dry matter, and for which the crops are primarily grown.

In dealing with the question of manuring, however, the farmer is more immediately concerned with the nature of the plant food which is taken from the soil by the roots of his crops.

From the soil the plants take up water holding in solution a variety of compounds, containing nitrogen, phosphoric acid, potash, lime, magnesia, sulphuric acid, iron, soda, chlorine and silica.

All these, except the last three are essential foods for every crop. Of the last three, possibly silica may be useful for cereals, and both soda and chlorine undoubtedly have a beneficial effect upon mangold, beet, and other plants of littoral origin, as shown by the increased yield which often results from applications of common salt.

The most important of the soil constituents absorbed by any crop are nitrogen, potash, phosphate and lime, and these are therefore the substances which must be specially considered in any system of manuring.

The other essential plant foods are present in suitable condition and in sufficient quantity in all ordinary cultivated soils.

Lime is deficient in some soils, and in such cases the remedy is evident, consequently our attention may be confined to nitrogen, potash and phosphate.

From the chemical analyses of soils it is often found that all essential ingredients are present in sufficient quantity to supply the necessities of vegetation for some thousands of years, and yet the crops grown in such situations may have been very light, and altogether unremunerative. There may be, for example, abundance of potash in the soil, amounting, perhaps, to several thousand pounds per acre in the first

9 inches, and yet it may be quite impossible to grow a remunerative crop of beans or clover on this land without the application of a potassic manure. The application to such a soil of 4 cwt. per acre of kainite, or 1 cwt. of muriate of potash, containing only about 50 lbs. of potash, may be quite sufficient to give a good paying crop instead of a losing one. The reason is that the potash in the soil is in such a state of combination, mainly with silica, as to form a compound or compounds, which will either not dissolve in water, or will do so but very slowly. As only that potash can be used by plants which enters their substance by the roots, it must first be dissolved by the soil water, either alone or aided by acids which the roots exude. Hence, not more than an infinitesimally small proportion of the total potash in a soil may be of immediate agricultural value. In kainite the potash is for the most part present as a sulphate, and in the "muriate" as a chloride, both of which readily dissolve in water, and thus become directly available for the use of the crop.

Farmyard manure is the oldest and most familiar, and as it contains not only nitrogen, potash, and phosphate, but also all the other plant foods mentioned above as being absorbed from the soil, it is, therefore, a complete manure. The composition varies very much according to the species, age, feeding, and other circumstances of the animals yielding the dung; the quantity and character of the litter used, the manner of its preparation, and, finally, the conditions under which it is kept before being applied to the land. *On the average a ton* (2,240*lbs.*) *of farmyard manure contains about* 12 *lbs. of nitrogen,* 12 *lbs. of potash, and* 6 *lbs. of phosphoric acid, a total of only* 30 *lbs. of the most important plant foods.*

Of nitrogenous manures, the most important are nitrate of soda and sulphate of ammonia; of the potassic manures, kainite, muriate of potash and sulphate of potash; and of the phosphatic manures, superphosphate, basic slag and bones.

In some respects artificial manures compare very favourably with farmyard manure, as the same quantities of plant foods to be found in one ton of the latter, are also contained in 195 lbs. of a mixture consisting of 80lbs. of nitrate of soda, 100 lbs. of kainite and 15 lbs. of best basic slag; or in 105 lbs. of a mixture consisting of 60 lb. of sulphate of ammonia, 25 lbs. of muriate or sulphate of potash, and 20 lbs. of superphosphate. Again, the whole of the nitrogen and potash, and a large proportion of the phosphate in either of the above mixtures, are

in such a condition as to be ready for the use of the crop during the season of application, whereas a very small part of these plant foods in the farmyard manure may become available during the first year.

Further, the proportion in which the nitrate, potash, and phosphate are present in farmyard manure is often not the best suited to the needs of the culture to which it is applied, whereas in the case of artificial manuring the proportions of the different plant foods can be varied to meet the requirements of each individual crop, at the same time making due allowance for the composition and physical properties of the soil on which it is grown. Hence, it often happens that a small quantity of a suitable artificial mixture will produce as great an increase in the produce as many times its weight of farmyard manure.

The above remarks should not be regarded as a disparagement of the natural article; they serve merely to indicate some of the advantages to be gained by the use of artificial fertilizers. Farmyard manure, on the other hand, possesses some advantages over the best artificial combinations in its mechanical effects upon the soil, more especially in the absorption and retention of moisture, and is, therefore, of the greatest value in a dry atmosphere, or in a dry season. The greatest difficulty is that sufficient cannot frequently be obtained for the production of heavy and really remunerative crops. The small percentage of plant food contained makes it necessary to apply a far larger quantity of it than can be produced on any farm, even where the stock receive a liberal supply of cake. With present day-rate of wages, and the low prices ruling for agricultural produce, the intelligent use of artificial manures becomes a matter of absolute necessity to the farmer.

On many farms there are fields whose position or difficulty of access renders the application of sufficiently large dressings of the bulky farmyard product, even when attainable, almost an impossibility. In such cases, experiments have already shown that good and highly remunerative crops may be secured by the use of artificials alone, the bulk and weight of which are so small in comparison, that their application is a matter of the greatest facility.

Of the three important classes of artificial fertilizers—viz., nitrates, phosphates and potash—the former two have been prominently brought before the attention of the farmers by numerous excellent treatises, pamphlets and booklets, and are generally better understood and more

extensively employed than the latter. Therefore, while recognizing the importance of these manures, and being convinced that their yet wider use would add greatly to the prosperity of the farmer, it is necessary to draw further attention to potash salts, a class which hitherto has not received the serious notice which it deserves.

The major portion of the potash salts is utilised in agriculture, and their demand for this purpose is steadily becoming greater year by year, as is shown by the following figures, calculated in "pure" potash (K_2O) :—

	1890. Tons.	1900. Tons.
Pure potash, used for agricultural purposes ...	71,679	255,722
" " " industrial purposes ...	50,623	70,257

From this it is evident that, while the increase in consumption for industrial purposes within the last eleven years only amounts to 39 per cent., the consumption for agricultural purposes during the same period has been more than trebled.

Consumption of Potash Salts for Agricultural purposes in different Countries.

Country.	Total consumption in tons calculated in Pure Potash (K_2O).					
	1895	1896	1897	1898	1899	1900
Germany	60,182	75,587	89,683	96,414	107,688	117,712
United States of America	33,907	38,018	46,628	51,663	50,855	66,595
France	5,033	5,892	7,266	6,532	8,772	8,229
Sweden	5,061	5,719	6,869	7,637	6,892	8,197
Holland	2,542	2,964	4,091	5,032	6,021	7,106
England			3,165	3,871	4,014	4,020
Scotland	4,088	4,569	1,487	1,782	2,584	3,370
Ireland			297	285	412	600
Belgium	2,881	2,681	2,829	3,110	3,367	3,607
Austria-Hungary ...	1,045	1,196	1,349	1,630	2,256	3,389
Spain	369	456	770	1,128	1,953	2,428
Denmark	834	1,071	1,030	1,375	1,320	1,692
Russia	467	620	625	1,011	1,037	1,597
Italy	883	792	938	1,235	1,197	1,380
Switzerland	833	876	953	931	1,038	1,026
Finland	181	332	466	566	505	382
Norway	69	107	164	252	238	286
Portugal...	68	46	44	119	13	43

From the above table it will be seen that, next to Germany, the United States of America are the largest consumers of potash salts for

manurial purposes; then follow France, Sweden, Great Britain, Holland, Belgium, &c.

Consumption of Potash per 100 Acres of Arable Land.

Estimated as Pure Potash (K_2O), in lbs.

Country	Arable Land in Acres*	1895	1896	1897	1898	1899	1900
Germany	86,971,300	152.5	191.6	227.3	244.3	273.0	298.3
Holland	5,012,100	111.7	130.3	179.9	221.3	264.7	312.5
Sweden	8,622,000	129.3	146.2	175.5	195.2	176.2	209.5
Scotland	3,641,200	77.3	86.3	90.0	107.8	156.5	204.0
Belgium	5,232,800	121.3	112.9	119.2	131.0	141.8	151.9
Denmark	6,305,000	29.2	37.5	36.0	48.1	46.1	59.1
England	16,915,400	33.3	37.2	41.2	50.4	52.3	52.4
Norway	1,412,900	10.7	16.7	25.7	39.3	37.1	44.7
Switzerland	5,258,700	35.0	36.8	40.0	39.0	43.5	43.0
U. S. of America ...	348,212,300	21.5	24.1	29.5	32.7	32.2	42.2
Finland	2,755,100	14.5	26.3	37.3	45.3	40.4	30.6
Ireland	5,322,500	10.6	11.9	12.3	11.8	17.0	24.8
France	92,649,800	12.0	14.0	17.3	15.5	20.9	19.5
Spain	72,201,100	1.2	1.4	2.3	3.5	6.0	7.4
Italy	50,421,000	3.8	3.5	4.1	5.4	5.3	6.1
Austria-Hungary ...	99,416,900	2.3	2.7	3.0	3.7	5.0	5.3
Portugal	11,329,000	1.3	0.9	0.9	2.3	0.3	0.8
Russia	515,055,200	0.2	0.3	0.3	0.4	0.4	0.7

*Cultivated Land under Crop and Grass, including permanent Pasture of Hay.

This table gives a very clear comparison of the extent to which potash is used in different countries per 100 acres of arable land. Germany heads the list up to the year 1900, when it was slightly surpassed by Holland, each using about 300 lbs. of potash, equal to 2,400 lbs. of Kainite. Then follow Sweden with 210 lbs., equal to 1,680 lbs.; Scotland with 204 lbs., equal to 1,632 lbs.; whilst in England and Wales only 52.4 lbs, equal to 420 lbs., and in Ireland 24.8 lbs., equal to 198lbs. of Kainite, were used. England is thus only seventh on the list, and Ireland, in spite of its millions of acres of moorland, which are specially benefitted by applications of potash, is twelfth. It uses only about 25 lbs. of pure potash per 100 acres, and when it is remembered that some districts in Germany require more than 1,500 lbs. per 100 acres, the contrast becomes an extremely marked one.

The following table will give details of the quantities of the various potash-salts used in Great Britain and Ireland.

Consumption of Potash for Agricultural Purposes in Great Britain, in tons.

	Percentage of Pure Potash.	1897	1898	1899	1900
A. England & Wales (16,915,390 acres arable land)—					
Kainite	12.4	12,265	15,947	18,867	20,064
Sylvinite	17.1	—	—	—	91
Muriate of Potash	50.5	1,802	1,861	1,653	1,290
Sulphate of Potash	48.6	1,064	1,483	1,250	1,219
Sulphate of Potash-Magnesia	25.9	315	352	316	456
Potash Manure Salt	28	264	334	—	—
	20	—	—	55	125
	30	—	—	339	433
Total		15,710	19,977	22,480	23,678
Equal to Pure Potash ...		3,115	3,810	3,951	3,957
Consumption of Pure Potash per 100 acres of arable land, in lbs.		41.3	50.5	52.3	52.4
B. Scotland (with 3,641,156 acres of arable land)—					
Kainite	12.4	6,932	8,876	14,154	17,788
Sylvinite	17.1	—	—	—	1,255
Muriate of Potash	50.5	744	740	932	778
Sulphate of Potash	48.6	22	55	27	22
Potash Manure Salt	28	738	910	—	—
	20	—	—	134	335
	30	—	—	968	1,595
Total		8,436	10,581	16,215	21,773
Equal to Pure Potash ...		1,464	1,754	2,544	3,316
Consumption of Pure Potash per 100 acres of arable land, in lbs.		90.0	107.9	156.5	204.0
C. Ireland (with 5,322,528 acres of arable land)—					
Kainite	12.4	2,285	2,180	2,795	3,746
Muriate of Potash	50.5	5	15	16	30
Potash Manure Salt	28	—	—	—	—
	20	—	—	5	—
	30	—	—	170	400
Total		2,290	2,195	2,986	4,176
Equal to Pure Potash ...		293	280	406	590
Consumption of Pure Potash per 100 acres of arable land, in lbs.		12.3	11.8	17.1	24.8

The greater facilities now afforded to farmers by County Councils and other public bodies for testing the value of artificial manures, and for obtaining reliable reports on carefully conducted experiments, combined with the absolute necessity of improving the manuring of land,

—all imperative demands of modern farming—will, no doubt, bring about a much more extensive use of potash in the future.

The following table shows the applications of phosphates and potash manures in Germany :—

A.—Comparative Use of Phosphates and Potash Manures.

Referring to Germany.	1893.	1896.	1899.
	Tons.	Tons.	Tons.
Superphosphate, Basic Slag, Bone Meal, Guano and other Phosphates, calculated as "Phosphoric Acid"	186,600	226,400	295,500
Potash Manures, calculated as "Pure Potash"	61,269	75,585	107,688

The figures show that in Germany there is used about three times as much phosphoric acid as pure potash.

In countries other than Germany the following table shows that the consumption of potash was even more largely exceeded by that of phosphoric acid.

B.—Comparative Use of Phosphates and Potash Manures.

Country.	Consumption per 100 acres of Arable Land in 1899, in lbs.	
	Phosphoric Acid.	Pure Potash.
Germany	749	273
Belgium...	1,729	142
Holland	575	265
Scandinavia	571	103
Great Britain	448	32
France	546	21
Switzerland	620	43
Italy	217	5
Austria-Hungary	120	5
Spain and Portugal	44	5
Russia	5	0·5

From the above it appears that the consumption of phosphoric acid was greatest in Belgium, and was 12 times as much as that of potash. Austria-Hungary used upwards of 22 times, and Italy as much as 40 times more phosphoric acid than potash.

This comparative consumption does not in any way represent the actual needs of crops. In 1899 British agriculture consumed, for

every 100 parts of phosphoric acid, only 7 parts of potash. On the other hand, for every 100 parts of phosphoric acid—

Clovers	require	140	parts	of potash.
Cereals	„	185	„	„
Potatoes	„	350	„	„
Mangolds	„	570	„	„

Potash manures, therefore, even in Germany, are not used to anything like an adequate extent. The more the question is examined, the more clearly will it be seen that the constant and universal complaint of crops is that they do not get enough potash. The very fact that years ago the world's supply of potash was drawn from the ashes of plants, proves its essential value as a manure, since the plants extracted this substance from the very soil on which they grew, and therefore required a return, if they were to continue to flourish. *Potash is found in the ash of all land plants, sometimes reaching* 50 *per cent., while in the case of ordinary farm crops, the quantity of potash present always far exceeds that of the phosphoric acid, and often that of the nitrogen.* This is shown in the following table, compiled from the results of a great number of analyses, by *Prof. Warington* :—

Quantity of Potash, Phosphoric Acid, and Nitrogen per acre removed from the Soil by Average Crops in lbs.

Average Crop	Potash	Phosphoric Acid	Nitrogen
1. Mangolds, 22 tons	300.7	49.1	138
2. Potatoes, 6 tons	77.6	24.2	67
3. Cabbages, 25 tons	24.0	6.1	16
4. Turnips, 17 tons	148.8	33.1	112
5. Meadow Hay, 1½ tons	50.9	12.3	49
6. Red Clover Hay, 2 tons	83.4	24.9	102
7. Beans, 30 bushels	67.1	29.1	106
8. Swedes, 14 tons	79.7	21.7	98
9. Wheat, 30 bushels...	28.8	21.1	48
10. Oats, 45 bushels	46.1	19.4	55
11. Barley, 40 bushels	35.7	20.7	48

A portion of the loss is replenished by the farmyard manure, but much is carried away in the bodies of the live stock, and in the milk, cheese, corn and other produce sold off the farm ; a considerable quantity also escapes in the drainage from the manure heaps. If, therefore, the fertility of the lands is to be maintained, these losses from the soil

must be compensated by the application of potash manure, as well as other additions. Where straw and fodder are sold off the farm, potash manures are specially necessary.

As indicated above, nitrates and phosphates are better known and more extensively used in this country than potash manures, and in many parts there are still farmers who use the two former to the exclusion of the latter. But, according to Liebig and other authorities on agriculture, not only must the three essential substances, viz., potash, phosphoric acid and nitrogen be present in the manure, but they must also be there in certain defined proportions, without which no proper crop can be obtained. Consequently, no excess of any one or of any two can suffice for growth when there is a shortage of the other one; if there is sufficient nitrogen and phosphoric acid for a full crop, but only enough potash for half a crop, half a crop only will be grown. Not only this, the excess of nitrogen and phosphoric acid is likely to be lost through drainage, dissipation in the case of nitrogen, or reversion into insoluble and unavailable forms in the case of phosphoric acid. It is, therefore, lack of prudence on the part of the farmer to use some food elements in great excess as compared with others. These points must be kept in mind in order to understand why, even with a liberal use of farmyard manure, crop-yields fall off.

Numerous experiments carried out at Rothamsted, and at many other places more recently started, with the aid of grants made by several of the English and Irish County Councils and the Irish Board of Agriculture, have also clearly verified these facts.

It is the practice to purchase manures specially compounded for each of the crops grown. By so doing more is paid for a given quantity of plant food than if the raw materials were either applied separately or mixed together by the farmer, for reasonably enough the manufacturer expects to be paid for his skill and trouble of mixing. With knowledge and care, it is better, especially where large quantities are employed, to buy the most suitable raw materials separately, and to apply each at its proper time, than to purchase a compounded manure, all the constituents of which are necessarily applied together, and cannot very well be adapted to the requirements of all classes of soils. For example, the best source of phosphate on a peaty or sour soil, or where there is a deficiency of lime, is basic slag, which should be applied in the autumn, whereas on some other soils superphosphate, applied in the spring, would be preferable. An autumnal use of kainite is in some

cases the best source of potash, whilst muriate or sulphate is more successful in others. A large proportion of nitrate of soda or sulphate of ammonia in the manurial dressings may be very remunerative on one soil, whereas on another a smaller proportion is preferable. Evidently, the knowledge of these differences may be most readily utilised by purchasing the raw materials separately, and applying each in season.

There are, however, many excellent compound manures, and special circumstances may render the use of them advisable in many cases. But care should always be taken to secure the application of a sufficient quantity of potash for each crop, either by requesting the manufacturer to include it in the mixture, or by sowing some potash-salts in addition to it.

The grass and clover manures on the market, otherwise excellent for their purpose, are often deficient in this sense.

Compounded or special manures should not be regarded as sufficiently rich in this respect unless they contain at least the following percentage of pure potash :—

Crop	Pure Potash
For Wheat, Barley and Oats	4 per cent.
,, Malting Barley	5 ,,
,, Turnips and Swedes	4 ,,
,, Meadows	5 ,,
,, Mangolds and Beet	5 ,,
,, Potatoes	5 ,,
,, Beans and Clover	7 ,,

In the event of preparations being used which contain less than the above proportions, the deficiency should be made good by the addition of kainite, or of one of the more concentrated potash-salts.

The potassium content of some soils, especially peat, chalk and sand, is very poor, and it is, of course, on these that the artificial addition produces the best results. Clay soils are usually rich in potash, but often the proportion immediately available for plant food is so small, that many excellent results, especially with clover and potatoes, have been obtained by the use of alkaline salts; even the richest clay, with a dressing of 6 cwt. per acre of kainite for mangolds, 4 cwt. kainite for clover or grass, and 2 cwt. per acre of muriate or sulphate of potash for potatoes, would produce a greatly increased crop.

Some crops are more responsive to this action than others; such are potatoes, beans, peas, clovers, sainfoin, vetches, mangolds and turnips. Potash is always required, and nc other substance can entirely take its place; but the above-named seem to be specially incapable of utilising the less soluble forms of potash naturally contained in the soil.

It often happens with this class of produce, as was proved in several experiments conducted during the past year, and referred to below, that an application of potash alone has given a highly profitable result. As a rule, however, these salts are used with the greatest advantage in conjunction with phosphate for leguminous species (beans, peas, sainfoin, vetches and clovers), and with phosphatic and nitrogenous mixtures for others. This is particularly the case when a system of artificial manuring is pursued for several years in succession.

Kainite is most profitably applied in the autumn, except for mangolds and the cabbage tribe; for these, however, it is the best form at other seasons. See further for special remarks on potatoes. The muriate and sulphate may be applied in the spring.

Each of the three important classes of manures has its special effects upon the *character* of the crop for which it is applied. Thus the nitrogenous manures greatly increase the production of leaf and the formation of chlorophyll or green colouring matter, and the phosphoric manures distinctly favour seed development.

Potash manures augment the yield of starch and sugars, the quality being at the same time improved; they are, therefore, specially serviceable in the production of good malting barley, superior potatoes and nutritious roots. Used in conjunction with nitrogenous manures they check the excessive development of chlorophyll, and also the too rank growth favoured by the former when used alone. They also neutralize the tendency of nitrogen class to delay the period of ripening.

As a dressing to pastures and meadows, potash manures, although benefiting the herbage as a whole, specially stimulate the clovers and other leguminous plants. They are also inimical to mosses and many weeds, and have a sweetening effect upon the pasture.

In the case of cereals these applications strengthen the straw, thus preventing lodging and permitting a larger quantity of nitrogenous manure to be used with advantage. With root crops they have the favourable effect already mentioned on the quantity and quality of the sugars which constitute the chief food value, and also check the disposi-

tion frequently manifested, especially on rich or heavily manured soils, to run to neck and leaf. In so doing they increase the proportion of the root or edible part to the leaves, which in most cases are finally of service only as a manure for the succeeding sowing.

Phosphate, alone or with nitrogenous manures, may answer very well for a time on some pastures, but if potash be many years omitted the yield falls to that of an unmanured field. The fact is strikingly illustrated on the grass plots at Rothamsted, which experimental farm should, if possible, be visited by every English agriculturist, for this and many other lessons.

Below are given a few results of cultivation experiments conducted by various official bodies and private landowners on farms in different situations in the British Islands. In calculating the cost of the manures the following prices are taken, except where otherwise stated :—Kainite £2 10s. per ton, muriate of potash £10 per ton, basic slag £2 10s. per ton, super-phosphate £2 15s. per ton, nitrate of soda £9 10s. per ton.

For much valuable information in this section I am indebted to Mr. E. B. Hadley, F.C.S., and Mr. D. Young, Editor of the *North British Agriculturist*.

THE POTATO CROP.

While it is usually necessary and beneficial to supply *complete* manures to all crops, yet at the same time one or other of the three important manurial ingredients holds a more prominent position in dealing with special departments. In growing potatoes addition of potash is the foremost necessity, from its influence on the quality of the tubers and the weight obtained, as well as from the difficulty experienced by the plant in the direct assimilation from any resistant potassium compounds which the ground may naturally possess. The potato is known to be very exhausting to the soil, as is seen by our table, hence the manuring must be liberal as well as complete. A free supply of farmyard manure is therefore usual, which may or may not be supplemented by artificial admixtures. Although well-prepared dung, under favourable circumstances, contains much potash, it will generally be found profitable to include an extra quantity in these additions. It may also be pointed out that where abundant supplies of farmyard manure are difficult to obtain, improvement, both in quality and amount of the produce, will result from applying it in more moderate doses (10 to 12 tons per acre),

and making up the deficiency with suitable mixtures of artificials. Experiments carried on for some years in the West of Scotland have indicated as a suitable mixture :—4 cwt. superphosphate, 1 cwt. sulphate of ammonia and 1½ cwt. sulphate or muriate of potash. It has also been shown by the same experiments that even in the total absence of the farmyard material a full success could be obtained by the use of artificial nutrients alone, and that the potatoes, instead of being spoiled, as is popularly supposed, were thereby improved. For such a purpose a similar mixture should be used in increased quantity, namely :—6 cwt. superphosphate, 2 cwt. sulphate of ammonia and 2 cwt. sulphate or muriate of potash, with 1 cwt. nitrate of soda applied later as a top dressing.

The following extracts from *Principal Wright's* Reports are illustrative of the beneficial effect of potash manures on potato cultivation.

Potato Experiments, West of Scotland Agricultural College, 1897.

Soil.	15 tons Farmyard Manure 4 cwt. Superphosphate		15 tons Farmyard Manure; 4 cwt. Superphosphate; 1 cwt. Sulphate of Potash.		6 cwt. Superphosphate; 2 cwt. Sulphate of Ammonia.		6 cwt. Superphosphate; 2 cwt. Sulphate of Ammonia; 2cwt. Sulphate of Potash.	
	Produce per acre		Produce per acre		Produce per acre		Produce per acre	
	Dressed	Total.	Dressed	Total	Dressed	Total	Dressed	Total
	T. cwt.	T. cwt.	T. cwt.	T. cwt.	T. cwt.	T. cwt.	T. cwt.	T. cwt.
Light Loam on Gravel	4 12	5 2	6 17	7 10	3 6	4 4	5 8	6 1
Medium Loam on Clay...	5 1	5 16	6 8	6 19	2 12	3 12	6 2	6 15

Total increase of crops produced by 1 cwt. sulphate of potash (with farmyard manure) = 2 tons 8 cwt. on light soil;

and 1 ton 3 cwt. on medium soil.

Cost of additional sulphate of potash = 8s. 4d.

Total increase produced by 2 cwt. sulphate of potash (without farmyard manure) = 1 ton 17 cwt. on light soil;

and 2 tons 3 cwt. on medium soil.

Cost of additional sulphate of potash = 16s. 8d.

Potato Experiments, West of Scotland Agricultural College, 1898.

Soil.	10 Tons Farmyard Manure; 4 cwt. Superphosphate; 1 cwt. Sulphate of Ammonia. Produce per acre.				10 tons Farmyard Manure 4 cwt. Superphosphate; 1 cwt. Sulphate of Ammonia 1 cwt. Sulphate of Potash. Produce per acre.			
	Dressed		Total.		Dressed		Total	
	Tons	Cwt.	Tons	Cwt.	Tons	Cwt.	Tons	Cwt.
Medium Loam	10	1	11	17	13	4	14	7
Loam on Clay Subsoil ...	8	17	11	9	10	6	11	19

In the one case the increase of crop due to 1 cwt. sulphate of potash was 3 tons 3 cwt. of dressed potatoes, and 2 tons 7 cwt. on the total crop; in the other, the dressed potatoes were increased by 1 ton 9 cwt., and the total crop by 10 cwt. These higher results were produced at a cost of 10s.

Potato Experiments, West of Scotland Agricultural College. 1899.

Manures applied per acre.	10 tons Farmyard Manure; 4 cwt. Superphosphate; 1 cwt. Sulphate of Ammonia. 1 cwt. Sulphate of Potash.			10 tons Farmyard Manure; 4 cwt. Superphosphate; 1 cwt. Sulphate of Ammonia; 1½ cwt. Sulphate of Potash,		
	Produce per acre. (Average of nine farms).			Produce per acre. (Average of nine farms).		
	Tons	Cwt.	Qrs.	Tons	Cwt.	Qrs.
Firsts	4	14	1	4	18	0
Seconds	1	18	1	1	19	3
Refuse	0	9	3	0	9	3
Total	7	2	1	7	7	2

Total increase produced by ½ cwt. sulphate of potash = 5¼ cwt.

Value of increase = 14s. 3d.

Cost of additional sulphate of potash = 5s. 3d.

The plot which received 10 tons farmyard manure, 4 cwt. superphosphate and 1 cwt. sulphate of ammonia produced a total increase of

crop over the unmanured plot of 3 tons; and when 1¼ cwt. sulphate of potash was added to that dressing a further increase of 1 ton 4 cwt. of potatoes was obtained, the extra outlay for the potash being 16s. 6d.

At Cardross Mills the results of the same series of experiments as in the previous case were as follows:—The heaviest yield of potatoes per acre (10 tons) was given by the plot which was manured with a complete mixture of artificials, consisting of 6 cwt. superphosphate, 2 cwt. sulphate of ammonia, 1 cwt. nitrate of soda and 2 cwt. sulphate of potash; while the plot which received farmyard manure alone produced only 7 tons 7½ cwts. per acre.

Mr. John Speir, of Newton records the results of experiments conducted by him, to the following effect:—

"The beneficial effects of potash are shown here in a most remarkable way. A complete manure, containing nitrate of soda, superphosphate and kainite, gave a total crop of 8 tons 12½ cwt. of potatoes per acre. When the nitrate of soda was omitted from the mixture the crop was reduced by 1 ton 6½ cwt., and when the superphosphate was omitted it was reduced by 2 tons 8¼ cwt. But the omission of the kainite caused the extremely large decrease in the crop of 3 tons 17 cwt. This enormous increase then was produced at a cost of only 4s. or 5s."

Dr. Somerville, Professor of Agriculture at Cambridge University, in his last annual report upon the experiments at the Northumberland County Council Demonstration Farm at Cockle Park, writes as follows:

"The addition of 7½ cwt. of mixed artificials with potash to 15 tons of farmyard manure has produced an average increase of 6½ cwt. of marketable potatoes. The addition of 1 cwt. of sulphate of potash, costing 9s., to the other artificials used with dung has resulted in a marked increase of crop on both sets of plots. The average improvement in the 'ware' was over 1½ ton in the one case, and nearly 1 ton in the other . . . It is also interesting to note the effect of potash on the proportion of 'small' to marketable potatoes. As an example, it may be mentioned that, where 15 tons dung, 1½ cwt. sulphate of ammonia, and 6½ cwt. superphosphate were applied, the percentage of 'small' to the total crop was twenty-five, whereas with the same manuring, *plus* 1 cwt. of sulphate of potash, the percentage of 'small' was reduced to eighteen. The same tendency is observable where the dressing of muriate of potash was doubled. With a single cwt. per acre, the percentage of 'small' potatoes was thirty-four, whereas it was only twenty-three where a double dressing of muriate was employed."

Professor Campbell, formerly Lecturer on Agriculture at the Glasgow Technical College, and now *Professor of Agriculture at Yorkshire College*, writes in his last annual report respecting the results of his last year's experiments in potato cultivation:—

"The importance of potash for the potato crop is well illustrated by a comparison of plots 8 and 12. The following are the figures:—

		Yield per Acre. Tons.	Cwt.	Qrs.
Plot 8	8 cwt. superphosphate ... ... 2 cwt. sulphate of ammonia ...	5	13	1
Plot 12	8 cwt. superphosphate ... ... 2 cwt. sulphate of ammonia ... 2 cwt. sulphate of potash ...	8	10	2
	Increase due to Potash	2	17	1

"This is one which has been confirmed by many other experiments, and must now be considered to have been established as a fundamental principle, and one which should be taken to heart by all potato growers."

In summing up the results of his experiments in potato growing, Professor Campbell states the following findings :—

"The application of potash along with the farmyard manure has been more profitable than any other artificial manure or combination of artificial manures used nnder similar conditions.

"Nitrate of soda along with farmyard manure resulted in no increase in the yield.

"The necessity of using potash as an ingredient of an artificial manure for potatoes has been forcibly demonstrated."

Mr. W. T. Lawrence, Director of the Cumberland County Council Demonstration Farm at Newton Rigg, gives the annexed account of experiments conducted there last season in the growing of potatoes :—

Plot.	Manure.	Cost. £	s.	Yield. Tons.	Cwt.
Plot 1	No manure			5	7
2	1½ cwt. nitrate ... ... 4 cwt. kainite ... ... 4 cwt. superphosphate	34	0	7	14
3	1½ cwt. nitrate ... ... 2 cwt. kainite ... ... 4 cwt. superphosphate	28	0	6	16
4	Half the artificials of plot 3, and 6 tons dung	14 (artificials)	0	10	7
5	12 tons of dung			10	8

"Up-to-date" was the variety growing.

Owing to the long period of drought during the past summer, the potato crop has averaged about 3 tons to the acre less than last year. The lessons of the two previous years are confirmed by this year's results, the best yields being obtained by 12 tons of good dung to the acre, or by 6 tons of dung and half the artificial dressing of plot 3. The best artificial dressing without dung again this year is that given to plot 2, but it is much further behind the dunged plots this year than it has been in other years, probably owing to the drought. The reduction of the amount of kainite (a potash manure) to anything less than 4cwt. to the acre when no dung is used, even on good land such as that ot Newton Rigg, has meant a serious diminution in the yield this year, as it has in previous years (compare lots 2 and 3.)"

It will be noted that this experiment stopped short at the application of 12 tons of dung—an application which yielded the maximum crop of 10 tons 8 cwt. of potatoes, which yield, however, was only 1 cwt. heavier than that obtained by an application of 6 tons dung, *plus* 1½ cwt. nitrate, 4 cwt. kainite, and 4 cwt. superphosphate. It may be safely said that if the experimenter had gone a step further, and followed the plan so successfully adopted by Dr. Somerville, namely, if he had added a liberal dressing of sulphate of ammonia, superphosphate, and potash to the 12 tons of dung, the crop so produced would have been very much heavier and still more profitable.

The great amount of attention that has been attracted to the findings of Dr. Somerville and Professor Campbell as to the conspicuous importance of potash as the "dominant manure" for potatoes led to a potato-growing competition being held in East Lothian last season for the purpose of further testing the point. This constitutes a most important department of agriculture in East Lothian, and the competition, which was conducted under the auspices of the East Lothian Agricultural Society, was entered into with great spirit. One of the conditions of this contest was that, alongside the crop competing for the prizes offered, there should be a plot of not less than half an acre grown with identically the same manures, except that the potash in this latter case was to be withheld. The competitors were free to apply the potash in any form which they preferred, but each and all of them, acting on the results of their previous experience, applied that manurial element in the form of kainite. Unfortunately, the potato crop in East Lothian suffered very severely from the extreme drought which prevailed all through the month of August, so that the yields recorded were much lower than they would otherwise have been. The directors of the Society appointed Messrs. Simpson, Castlemains; Ronaldson, Kilduff; and Cairns, Prora, to inspect and weigh the various crops submitted; as the result of this inspection and weighing, the first prize was awarded to Mr. Wallace, Hailes, Haddington, and the second to Mr. W. W. Anderson, of Kingston. The weights of these crops were stated as follows in the official report :—

		HAILES.	T. C. Q.	T. C. Q.
(Potash)	Ware	... ...	10 13 3	
	Small	... ...	2 5 0	
				12 18 3
(No Potash)	Ware	... ...	9 15 2	
	Small	... ...	2 11 0	
		KINGSTON.		12 6 2
(Potash)	Ware	... ...	9 1 0	
	Small	... ...	2 2 2	
				11 3 2
(No Potash)	Ware	... ...	7 13 0	
	Small	... ...	3 3 3	
				10 16 3

The first prize competition crop at Hailes was manured with 20 loads of dung, supplemented with a mixture of artificials made up as follows :—1 cwt. sulphate of ammonia, 1 cwt. Peruvian guano, 2 cwt. superphosphate, 3 cwt. kainite and 1 cwt. bone meal. In the unpotashed lot the crop was manured in precisely the same way, except that the 3 cwt. of kainite was withheld. The result was that the withholding of the 3 cwt. of kainite, which would have cost about 9s., led to the yield of "ware"

—marketable tubers—being reduced by 18 cwt., or by a money value of 55s. per acre. The weights of the Kingston plots are notable on account of the fact that this fine holding, which is so highly farmed by its enterprising owner, is situated near the sea, and it is often said that land which is near the sea does not require any artificial potash to be applied to it, as sufficient muriates are carried from the sea by the winds to such land. Yet here, as the weights showed, the addition of 3 cwt. per acre of kainite to this very rich land raised the yield of "ware" by 28 cwt., or a money value of at least £4 per acre.

In the experiments which were conducted for ten years in Wiltshire, under the auspices of the County Council, excellent crops were obtained by the use of 4 cwt. each per acre of kainite, superphosphate and nitrate of soda, on three different kinds of soil, viz., heavy clay, loam, and calcareous clay. By far the most profitable crops were obtained, however, with 8 tons of dung together with 2 cwt. each of kainite and nitrate of soda. On a large number of soils the addition of phosphate would no doubt be an advantage. If kainite be used in the case under consideration, it should be applied to the previous crop, or at least in the autumn, before the tubers are planted. If this is not possible, the muriate or sulphate of potash should be used instead of kainite. The nitrogenous manure should be applied in two or more fractional top dressings of not more than 1 cwt. per acre each; the first soon after the leaves appear above ground, and the remaining ones at intervals of about three or four weeks. Where a large quantity of nitrate or sulphate of ammonia is used for other crops, it should be applied in a similar manner. Where basic slag or bones are used they should be applied in the autumn. Superphosphate may be applied in the spring.

Potato Experiment at Sexey's School, Wedmore, Somerset, 1901.

Experiments with the potato crop were carried out on the light sandy soil adjoining this school by the Head Master, Mr. E. H. Smith, in 1901, for the second time, when the following results were obtained :—

Manures per acre.	Yield per acre.		Excess from manured over unmanured plot.		Cost of Manure.			Profit on Manure.		
	Tons	Cwt.	Tons	Cwts.	£	s.	d.	£	s.	d.
No Manure ..	11	0	—		—			—		
Kainite, 4 cwt. ... Nitrate of Soda, 4 cwt.	13	10½	2	10½	2	8	0	3	18	3

In this experiment it is seen that the use of 4 cwt. each of kainite and nitrate of soda, costing £2 8s., produced an increase of 2 tons 10½ cwt. of potatoes, valued at £6 6s. 3d., thus showing a profit of £3 18s. 3d. on the manures used.

Potato Experiment at Cornish Down, Tenby, South Wales, 1901.

This experiment was conducted by Mr. D. Hinds on medium soil in fair condition on his own farm :—

Manures per acre.	Yield per acre.		Excess from manured over unmanured plot.		Cost of Manure.			Profit on Manure.		
	Tons	Cwts.	Tons	Cwts.	£	s.	d.	£	s.	d.
No Manure ...	8	8	—			—			—	
Kainite, 4 cwt. ...	10	0	1	12	0	10	0	3	10	0
Kainite, 4 cwt., and Basic Slag, 4 cwt.	10	8	2	0	1	0	0	4	0	0

This experiment shows an increase of 2 tons of potatoes, valued at £5, from the use of 4 cwt. each of kainite and basic slag, costing £1 ; and of 1 ton 12 cwt., valued at £4, from the use of only 10s. worth of kainite.

Potato Experiment at Carterton, Oxford, 1901.

The experimenter here was Mr. F. W. Wallis, well-known for his great success with chrysanthemums. The soil is a medium clay in poor condition resting on limestone. The muriate of potash was applied too late to show its full effect upon the crop, but nevertheless the result obtained may be worth recording. It was as follows :—

Manures per acre.	Yield per acre.		Excess from Manured over Unmanured Plot.		Percentage increase from Manures.	Cost of Manure.			Profit on Manure.		
	T.	Cwt	T	Cwt.	%	£	s.	d.	£	s.	d.
No Manure	4	6½	—		—		—			—	
Muriate of Potash, 1½ cwt.	4	17¾	0	11¼	13	0	15	0	0	13	1
Sulphate of Ammonia, 4 cwt. Phosphate, 4 cwt.	5	16¼	1	9¾	35	2	12	0	1	2	4
Muriate of Potash, 1½ cwt. ... Sulphate of Ammonia, 4 cwt. Phosphate, 4 cwt.	6	5⅛	1	18⅞	45	3	7	0	1	10	2

We have in this case an illustration of the advantage of using a complete manure for potatoes, both as regards weight of crop and profit. The complete manure, consisting of muriate of potash, sulphate of ammonia and phosphate, increased the yield by nearly two tons, at a cost of £3 7s.

Valuing the increase at £4 17s. 2d., the profit arising from the use of this complete manure amounts to £1 10s. 2d.

The effect of the muriate of potash is seen by comparing the yield of plot 4 with that of plot 3, and of plot 2 with plot 1. The omission of potash from the complete manure reduced the profit from £1 10s. 2d. on plot 4 to £1 2s. 4d. on plot 3, and the use of potash alone increased the yield over the unmanured plot by 11¼ cwt., and gave a profit of 13s. 1d. Had the experiment been carried out under more favourable conditions, the yield of all the plots would have been greater, and the difference between the manured and unmanured plots doubtless more marked.

Under the circumstances it is interesting to note the percentage increase on the manured plots.

Potato Experiment at Needham, Isle of Ely, 1901.

In the report on investigations carried out in 1901 under the Agricultural Department of Cambridge University, there will be found at page 131 a statement of the results obtained in a potato-manuring experiment on a silt soil at the above locality. The weights given in the appended table are extracted therefrom.

Manures per Acre.	Yield per Acre.	Excess of manured over unmanured plot.	Value of Excess.	Cost of Manure.	Net Profit.
	Tons cwts.	Tons cwts.	£ s. d	£ s. d.	£ s. d.
No manure	5 7¾	—	—	—	—
Superphosphate, 5 cwt. ...	5 11	0 3¼	0 8 2	0 13 9	—
Muriate of Potash, 1 cwt. Superphosphate, 5 cwt.	7 13	2 5¼	5 13 2	1 3 9	4 9 5

From the above it will be seen that the application of 1 cwt. of muriate of potash and 5 cwt. of superphosphate increased the yield by over 2¼ tons, and gave a profit of £4 9s. 5d. By omitting the muriate of potash the yield was reduced by over 2 tons, and there was a loss on the manure used. It may be noted that this result does not show the

phosphate to be useless ; it rather indicates that the full benefit of the phosphatic dressing could not be obtained without the addition of potash. The crop on this soil needed phosphate, but still more so potash.

Potato Experiment at Bramford, Suffolk, 1901.

The trials in this locality were conducted under the East Suffolk County Council on poor, light, gravelly soil.

Considering the plots sprayed with the Bordeaux mixture, we find that the yield of the unmanured plot was 3 tons 18½ cwt., whilst that of an adjoining plot, which was manured with muriate of potash at the rate of 2 cwt. per acre, was 7 tons 8½ cwt. Hence, at a cost of £1 for manure, the yield was more than doubled, and exceeded that of the unmanured plot by 3 tons 10 cwt. The value of the increase obtained with the muriate of potash may be taken as £8 15s., and therefore the profit on the manure used as £7 15s.

Enough has, perhaps, been said to show beyond doubt that in the case of potatoes, whether farmyard manure is applied or not, a serious reduction is occasioned and less profitable results are obtained by the failure to apply potash manures.

MANGOLDS.

Among roots, mangolds are now regarded by many farmers, especially those in the south of England, as the most important and reliable, and in many counties they are gradually superseding turnips, while they are distinguished as pre-eminent in their ready response to liberal dressings of manures. Their composition, more than that of any other crop, is affected by the nature of the fertilizers used in their growth. They are usually cultivated with liberal supplies of farmyard manure. More copious dressings of nitrogenous and potassic compounds may be used with special advantage ; the soil alone is, as a rule, sufficient to provide the greater part of the phosphate required.

Numerous experiments show that heavier results with mangolds are obtained by the aid of artificials alone, and at less cost than with farmyard manure alone ; but usually the weight of produce is the largest under a small dressing of dung supplemented by artificials.

The proportion of root to leaf and the percentage of sugar in this species has been proved to depend greatly upon the presence of an adequate supply of potash. Nitrogenous manure, more than the rest,

determines the weight of the crop, and the extent to which this adjunct can be most profitably employed will be determined by season and local conditions, but it is important to remember that the larger the quantity of nitrate or other nitrogenous manure used, the larger must also be the supply of potash. In many parts of the country, especially in those most distant from the sea, a dressing of about 3 cwt. of salt will be found valuable.

When grown without farmyard manure the following quantities of artificials are recommended :—

Kainite 4 cwt., salt 3 cwt., superphosphate 1 cwt., or equivalent of basic slag; and nitrate of soda 4 cwt., or equivalent of sulphate of ammonia. On land which is light and sandy it might be found preferable to dispense with the salt and use 6 or 7 cwt. of kainite instead of 4 cwt., as this latter manure contains a large percentage of common salt, and potash is more needed on such a soil.

Where dung is used, say, 16 loads per acre, half the above quantities of artificials would usually suffice.

The following results of recent experiments with mangolds are of considerable interest. Where the profit arising from the use of manure is given, the roots are valued at 10s. per ton.

Mangold Experiment at Aspatria College, Cumberland, 1901.

On account of the significance of the results, Mr. H. F. Hill's report is given in entirety.

"The experiments with mangolds this year were carried out almost on the same lines as those with swedes last year, and were designed with the idea of bringing out the following points :—

(1) To demonstrate the comparative effects of nitrogenous, phosphatic and potassic manures used singly.

(2) To show the superiority of a mixed manure over a single one.

(3) To compare the effects of artificial mixtures with a dressing of farmyard manure.

(4) To show the advisability of applying a well-selected top dressing of artificials in combination with farmyard manure.

The plots were each one-sixteenth of an acre in extent, and the manure on each plot, from 2 to 8 inclusive, cost at the rate of 36s. per acre. During the first eight or ten weeks the plots manured with phosphates appeared to be taking the lead, but they were closely followed by those maunred with nitrogen. The potash plot (No. 3) during this period

looked no better than the unmanured one; but from the middle of July onwards, as soon as bulbing commenced, the potash plots rapidly improved, and by the end of the month took the lead in both the single and mixed manure series, being closely followed by the nitrogenous plots. The potash plots were easily distinguished from all the others by their characteristic tall, pale green leaves, which made a marked contrast with the dark leaves of the nitrogenous plots. The mangolds were lifted, topped (not tailed), and weighed at the end of October. The following table gives the results worked out per acre, obtained from the weighing :—

No. of Plot	Description of Plot	Manure Used Per Acre	Yield Per Acre	
			tons	cwt.
1	Unmanured	None	21	13
2	Phosphate	13 cwts. Superphosphate	22	2
3	Potash	14 cwts. Kainite	30	7
4	Nitrogenous	3½ cwts. Sulph. of Ammonia ...	23	13
5	Nitrogenous	4 cwts. Nitrate of Soda	28	0
6	Phosphoric Acid and Potash	7 cwts. Superphosphate ... ... 7 cwts. Kainite	31	19
7	Nitrogen and Potash ...	1 cwt. Sulph. of Ammonia ... 1 cwt. Nitrate of Soda ... ... 7 cwts. Kainite	33	2
8	Nitrogen, Potash and Phosphoric Acid ...	1 cwt. Sulph. of Ammonia ... 1 cwt. Nitrate of Soda ... ... 4 cwts. Kainite ... ... 3 cwts. Superphosphate	30	5
9	Farmyard Manure ...	16 loads	27	4
10	Farmyard and artificial ...	Farmyard, 16 loads ... ... 2 cwts. Nitrate of Soda ... ... 2 cwts. of Salt	34	16

Plots Nos. 4 and 5 received half the manure previous to sowing the seed on April 25th, and the remainder as a top-dressing at the end of July. Plot 10 received its top-dressing of nitrate of soda and salt at the same time.

A study of the table enables one to see all the points aimed at, clearly brought out by the experiments. In the single manure series the potash plot produced the best crop; in addition to its greater weight the roots were better shaped and more matured than those of the other plots of this series.

The nitrogenous plots came next to the potash, and in this section the nitrate of soda showed its superiority over sulphate of ammonia, which strongly suggests that the combined soda in the nitrate has a very beneficial influence on the mangold crop.

Although the superphosphate plot started so well the final result was very little superior to that of the unmanured plot.

Turning now to the mixed manure series, it will be noticed that, although superphosphate made such a bad show when used alone, in combination with potash it produced a crop superior to that obtained by potash alone ; but when nitrogen was substituted in place of superphosphate in combination with potash, the results were still better. The nitrogen thus proved itself to be a better partner for potash than superphosphates. In plot 8 superphosphate was tried as a substitute for part of the potash in combination with nitrogen, but it failed to give such good results (compare plots 7 and 8). As the manures used on the plots in question cost the same, it shows very conclusively the economy in using potash and nitrogen in preference to phosphates for the mangold crop.

In the farmyard manure section the plot dressed with farmyard manure alone was beaten by most of the artificial manure plots, but when aided by a top-dressing of nitrate of soda and salt the result was most satisfactory, as the yield was larger than that of any other plot.

It was very noticeable with the mangolds that the more potash applied the more matured was the crop at the time of lifting. This to the north-country farmer is very important, as the earlier the crop matures the greater are the chances of getting the crop lifted before the frost sets in."

It may be well here to further note that—

1. Potash alone at a cost of 36s. yielded 8 tons 14 cwt. more mangolds than were obtained from the unmanured plot. The excess may be valued at £4 7s., and gives a profit of £2 11s.

2. Nitrogen and potash at a cost of 36s. increased the yield over the unmanured plot by 11 tons 9 cwt., value £5 14s. 6s., and thus gave a profit of £3 18s. 6d.

3. The heaviest crop was obtained by farmyard manure supplemented by artificials, but at greater cost, so that the profit was much less than in the case of plots 3 and 7.

MANGOLD EXPERIMENT AT CALNE, WILTS., 1901.

The trials were carried out on very heavy land by Mr. Gingell, with the following results:—

Plot	Manures Per Acre	Yield Per Acre	Excess from manured over unmanured plot	Value of Excess	Cost of Manure.	Net Profit on Manure Used
		tons cwt.	tons cwt.	£ s. d.	£ s. d.	£ s. d.
1	No Manure...	24 9	—	—	—	
2	Nitrate of Soda, 4½ cwt. ... Superphosphate, 2 cwt. ... Salt, 3 cwt....	47 19	23 10	11 15 0	2 8 3	9 6 9
3	Kainite, 4 cwt. ... ... Nitrate of Soda, 4½ cwt. ... Superphosphate, 2 cwt. ... Salt, 3 cwt....	50 17	26 8	13 4 0	2 18 3	10 5 8

No Manure.	Complete Manure, less Potash.	Complete Manure, including Potash.
24 tons 9 cwt.	47 tons 19 cwt.	50 tons 17 cwt.

Mangold Experiment, Cornish Down, Tenby, S. Wales, 1901.

Complete manuring, involving the use of nitrate of soda, kainite, superphosphate and salt, here increased the yield by nearly 26½ tons at a cost of only £2 18s. 3d., and gave a profit of £10 5s. 8d. It is interesting also to note that the omission of kainite, costing 10s., from the complete manure caused the yield to be nearly 3 tons, and the profit about £1 less.

Mangold Experiment, Cornish Down, Tenby, S. Wales, 1901.

An investigation conducted by Mr. Hinds on his own farm. The land on which the crop was grown was neither very heavy, nor very light, and was in fair condition. Yard manure had been applied for the previous crop and not directly for mangolds.

One plot received a dressing of 4 cwt. per acre of kainite, and another none. The yield of the former plot was 24 tons, and of the latter 18 tons. Hence an expenditure of 10s. on kainite increased the yield by 6 tons and gave a profit of £2 10s.

Mangold Experiment, Patterdown, Wilts., 1901.

This experiment was tried by Mr. J. H. Wilcox, on his own farm, on very light soil with a subsoil gravel. One plot was dressed with 2 cwt. of nitrate of soda per acre, and yielded 37 tons 11½ cwt. of

mangolds per acre, whilst an adjoining plot was manured with 2 cwt. of nitrate of soda, and 1½ cwt. of muriate of potash per acre, and yielded 47 tons 10½ cwt. per acre. Hence the application of 1½ cwt. of muriate of potash, costing 15s., increased the yield by 9 tons 19 cwt. Valuing the roots at £4 19s. 6d., a gain of £4 4s. 6d. was obtained from the use of 1½ cwt. of the muriate.

THE TURNIP CROP.

The turnip is far more abundantly grown in Scotland than any other root. Like potatoes it requires liberal treatment, and it is the custom in many parts of the country to apply to the fields of turnips manures which are expected to be sufficient to satisfy all the other crops throughout the whole rotation.

In respect to the turnips themselves, numerous experiments have shown that an abundant product can be grown by the application of moderate, not large, dressings of farmyard manure, supplemented merely by 4 or 5 cwt. of superphosphate per acre. When turnips are raised, therefore, by the aid of farmyard manure, it is, as a general rule, unnecessary to apply either nitrogen or potash. That fact has, in consequence, been frequently taken to imply that turnips do not require potash at all. The season's yield of turnips will remove from the soil almost twice as much potash as a similar harvest of potatoes—nearly 150 lbs. per acre ; and it seems quite unreasonable to suppose that the turnip, although it has a special faculty for absorbing potash, is able to secure its full supply of that ingredient from the slowly available and somewhat limited store of potash contained in most soils. On the contrary, it has been conclusively shown that, where in the culture mixtures of artificial manures are substituted for ordinary dung, they must be complete, *i.e.*, must include the proper proportions of nitrogen, phosphates and potash. Generally speaking, the phosphates should be in the soluble form, either superphosphate or dissolved bones ; but where there is a liability for the turnips to be affected with "finger and toe," the use of dissolved manures cannot be recommended, and their place should be taken either by the finer samples of bone meal, steam bone-flour, or basic slag. These should all be applied in quantities equivalent to about 6 cwt. superphosphate per acre. If to this is added 3 cwt. of kainite, and 1 cwt. nitrate of soda or sulphate of ammonia, it will be found that full and profitable crops of turnips can be grown where circumstances necessitate the use of artificial manures only.

Reference to the results of experiments carried out during recent years in the West of Scotland will fully bear out this statement.

Turnip Experiments—West of Scotland Agricultural College—1899.

MANURES APPLIED	Produce of Roots Per Acre Average of 12 Farms	
	tons	cwt.
Phosphatic and Nitrogenous Manures (without Potash) ...	16	4¼
Same, with 3 cwt. Kainite	17	11¼
Increase due to 3 cwt. Kainite	1	7

The increase of 27 cwt. of turnips per acre produced by 3 cwt. kainite costing about 8s., would be quite satisfactory in any season ; but since this result was obtained at a time when turnips in most places were very much below the average, a far greater value can be attached to the figures. The soil on the majority of the twelve farms on which the essays were conducted was of a fairly light character, but on one, where the soil was distinctly heavy, the 3 cwt. kainite originated the remarkable increase of 3½ tons per acre.

Turnip Experiments—West of Scotland Agricultural College—1900.

MANURES APPLIED	Produce of Roots Per Acre Average of 12 Farms	
	tons	cwt.
Phosphatic and Nitrogenous Manures (without Potash) ..	21	15
Same, with 3 cwt. Kainite	23	10
Increase due to 3 cwt. Kainite	1	15

With a much heavier crop the increment due to potash was greater in about the same proportion.

On the average of 16 farms the increase produced by 8s. worth of kainite shows an even larger percentage of profit.

In one case with a light loam soil, the mixture which gave the smaller result was—

6 cwt. superphosphate. 1½ cwt. dissolved bones.
1½ cwt. bone meal. 1 cwt. sulphate of ammonia.

Yield without potash, 23 tons 15 cwt.
,, with potash, 27 tons.

Increase from 2 cwt. kainite and 1 cwt. sulphate of potash, 3 tons 5 cwt.

In its incomplete state, through the absence of any manure containing potash, the above may still be regarded by many as a fairly liberal dressing. Yet, when potash manures, costing about 12s., were added to it, the highly satisfactory improvement of 3 tons 5 cwt. was obtained, an increase of nearly 14 per cent.

In another case the mixture without the potash was—

3 cwt. superphosphate.	3 cwt. dissolved bones.
3 cwt. bone meal.	1 cwt. sulphate of ammonia.

Weight of crop (without potash),	17 tons 18 cwt.
„ „ (with potash),	25 tons 3 cwt.
Increase due to 4 cwt. kainite,	7 tons 5 cwt.

The fact that the use of 4 cwt. kainite (costing 11s.) augmented the yield by 7 tons 5 cwt., or 40 per cent., affords further proof of the high value which these alkaline salts possess in enabling the plants to take full advantage of unusually large applications of phosphates.

The foregoing statistics clearly establish, even without further examples, the benefit derived from the addition of potash compounds in the cultivation of this root.

To the same import Dr. Somerville, in his annual report of the trials conducted in 1898 on the Northumberland County Council Demonstration Farm at Cockle Park, says :—

"We have again, at Cockle Park, had a remarkable example of the value of potash, in the turnip manure employed without dung.

"A dressing of $1\frac{3}{4}$ cwt. of sulphate of ammonia and 7 cwt. superphosphate gave a crop of 8 tons 3 cwt., whereas the crop got by the same substances *plus* 6 cwt. kainite, weighed 25 tons 5 cwt. It is worthy of note that the crop was 5 tons lighter where sulphate of ammonia and superphosphate were employed without kainite, than it was on the land getting no manure whatever. This result is similar to that obtained at the same place in 1897, and shows that, in an extreme case, such as is presented at Cockle Park, artificial manures without potash used for the turnips on tillage land may do more harm than good."

The significance of the conclusion received a wide attention and the enterprising agriculturists in the Stewartry of Kirkcudbright decided in the spring of last year to have the value of potash in this department of agriculture as fully tested by a turnip-growing competition, in which each of the competing crops, grown with potash in combination with other manures, should have alongside of them half an acre of roots grown under precisely the same conditions, and with precisely the same manures, except that the potash should be withheld. Messrs. Robeson, Laurieston Hall, and Brown, of the Hermitage, Castle-Douglas, were appointed to inspect and weigh the different crops, and their report has been published in the following terms :—

"The extreme drought which prevailed all through the month of June acted most disastrously on the turnip crop all over the country; and the Stewartry was

as hard hit in this respect as probably any other part of the kingdom,, so that the weights per acre recorded are much below the average yield of good average land in that quarter. The judges, after inspecting and weighing the crops have awarded the first prize to Mr. Allan, Howwell, for a crop which showed a yield of 20 tons 7½ cwt. of roots and 2 tons of 'shaws.' On the adjoining plot of half an acre, from which the potash had been withheld, the crop weighed 15 tons, 18¾ cwt. of roots, and 1 ton 12¾ cwt. of 'shaws.' The soil was a heavy clay, and the manure applied to the competing crop consist of 1 cwt. sulphate of ammonia, 4 cwt. bone meal 6 cwt. superphosphate, and 1½ cwt. sulphate of potash. On the unpotashed plot, the treatment was in every way the same, except that the potash was withheld. The results in this case, therefore, showed an increase of crop to the extent of 4 tons 9 cwt. of bulbs and 8 cwt. of 'shaws,' through the addition of the 1½ cwt. of sulphate of potash. The second prize was awarded to Sir Mark J. M'Taggart Stewart, Bart., M.P., of Southwick, for a crop which weighed 19 tons 10¼ cwt. of bulbs and 1 ton 14¼ cwt. of 'shaws.' On the adjoining half-acre plot, grown with the same manurial mixture, except that the potash was withheld, the crop weighed 12 tons 2 cwt. of bulbs and 1 ton 12¾ cwt. of 'shaws.' The soil was of a sandy character, and the manures applied consisted of 5 cwt. bone meal, 2 cwt. dissolved bones, 1 cwt. muriate of potash, 1 cwt. sulphate of ammonia, and 3 cwt. superphosphate. In this case, therefore, the results showed an increase of crop to the extent of 7 tons 8¼ cwt. of bulbs and 2½ cwt. of 'shaws,' through the addition of 1 cwt. muriate of potash to the manurial mixture. Mr. Robertson, Twynholm Mains, and Mr. Lusk, Airieland, came next in order, the former with a crop of 15 tons, and the latter with a crop of 12 tons 3 cwt."

Mr. James Shields, Dolphinstone, Tranent, records an equally striking demonstration of the value of potash in the manuring of the root crop. Mr. Shields, who is well and widely known as one of the most skilful, enterprising, and successful farmers in East Lothian, has related his experience in this matter as follows :—

"On 20th January, 1896, I sowed a 30-acre field, good friable loam, about 300 feet above sea-level. Being very steep, and almost impracticable to cart farmyard manure up to it, there would be little cumulative fertility about it. In 1892 it was also in turnips a splendid braird, fine plants to the hoe, but after that a miserable crop. Though twice top-dressed with nitrate during the season, they were all eaten on the field with sheep—getting cake and hay. 1894, the young grass also eaten with sheep, but, being poorly planted, was again ploughed up.

"The artificials sown at above date were 6½ cwt. slag, 2¾ cwt. kainite, and 2 cwt. bone meal per acre. The field was ploughed in December, marked off into 18-feet ridges across the field, and sown with broad cast grain sower. About the middle of the field I left two ridges *without the kainite*, and everything else the same.

"On 12th May commenced sowing turnips, drilling up and down, thus crossing two ridges missed with kainite. The artificials given in the drill were:—

2 cwt. Liebig guano	£0	13	0
3 cwt. 35 per cent. supers, 2s. 2d, ...	0	8	3
2 cwt. dissolved bones, 4s.	0	8	0
¾ cwt. sulphate of ammonia, 8s. 3d.	0	5	9
Total cost of both dressings, about 5s. per acre.	£1	15	0

"That year there was a good sound crop of turnips, all swedes, with the exception of about 3 acres of yellows at each side of the field. The kainite-missed rigs were almost nil, and could be seen miles away from the field, and looked like a bare headland right across the field. The yellows were not quite so marked as the swedes.

"It was quite evident to me that my labour and money would have been entirely lost had I not had this 5s. worth per acre of kainite."

Mr. Thomas Blair, Hoprig Mains, Macmerry, another East Lothian farmer, had an equally striking experience this last season as to the

value of kainite in the manuring of the turnip crop. While most of the other farmers in East Lothian—or the country—had a very disappointing crop on account of the disastrous drought in June, which ruined the braird (sprouting), Mr. Blair's showed splendidly, and it was recently announced in the public press that, besides feeding a "head" of stock quite as large as that usually fed on a farm of the same size, he had last autumn sold 400 tons of swedes at 25s. per ton, free on rail, thereby realising for a comparatively small portion of this produce a sum equal to the whole amount of his rent. The turnip crop, which proved so highly satisfactory to him in such an unfavourable season, was manured with 18 tons dung, supplemented with 2 cwt. sulphate of ammonia, 4 cwt. superphosphate, and 4 cwt of kainite. Keeping in mind the experience of Mr. Shields, as above recorded, Mr. Blair withheld the 4 cwt. kainite from a half acre of his field, and in that half acre the deficiency of the crop was as marked as it was in the case of the field at Dolphinstone, even although a good dressing of farmyard manure had in this case been applied.

The results shown in the table below were obtained by *Captain Wolfe* with a loamy soil on his own farm.

Turnip Experiments, Rockford, Co. Tipperary, 1899.

Plot.	Manures per acre.	Yield per acre.		Excess from manured over unmanured plot.		Cost of manure.		
		Tons.	cwts.	Tons.	cwts.	£	s.	d.
1	No Manure	11	4¼	—		—		
2	Nitrate of Soda, 1 cwt. Superphosphate, 4 cwt.	16	14	5	9¾	1	0	6
3	Kainite, 4 cwt. Nitrate of Soda, 1 cwt. Superphosphate, 4 cwt.	20	18¾	9	14½	1	10	6
4	Dung, 30 tons	17	2¼	—		—		

In this instance it is clearly seen that the complete chemical manure, consisting of kainite, nitrate, and superphosphate, gave a greater yield than the heavy dressing of dung (30 tons), and that this yield exceeded that from the unmanured plot by 9 tons 14½ cwt. The cost of the manure to obtain this addition of crop was only £1 10s. 6d., so that the extra turnips cost about 3s. per ton.

It will also be observed that the omission of kainite from the otherwise complete manure, caused a loss of about 3¼ tons of turnips.

Turnip Experiments, Ballycarney, Co. Wexford, 1899.

Plot.	Manures per acre.	Yield per acre.		Excess from manured over unmanured plot.		Cost of manure.		
		Tons	cwts.	Tons	cwts.	£	s.	d.
1	No Manure	3	16½	—		—		
2	Nitrate of Soda, 1 cwt. Superphosphate, 4 cwt.	14	15½	10	19	1	0	6
3	Kainite, 4 cwt. Nitrate of Soda, 1 cwt. Superphosphate, 4 cwt.	15	16¾	12	0¼	1	10	6
4	Dung, 30 tons	13	2¼	—		—		

In this case the experiment was carried out by *Mr. T. A. Rudd* on light soil.

Again, in this experiment, the complete chemical manure gave a heavier crop than dung. By the expenditure of £1 10s. 6d. on manure the crop was increased by nearly 11 tons. The omission of kainite reduced the crop by more than a ton.

The Midland Agricultural and Dairy Institute, Kingston, Derby, reports the following results, obtained in an experiment tried on gravel soil :—

Experiments with Swede Turnips, Muskham, 1900.

Plot.	Manures per acre.	Yield per acre.		Excess from manured over unmanured plot.	
		Tons	Cwts.	Tons	cwts.
1	No Manure	11	0¼	—	—
2	Dung, 10 loads	12	19½	1	19¼
3	Kainite, 1½ cwt. ... ... Superphosphate, 1¾ cwt. Nitrate of Soda, ¾ cwt....	13	4	2	3¾
4	Dung, 10 loads ... ... Kainite, 1½ cwt. ... ... Superphosphate, 1¾ cwt. Nitrate of Soda, ¾ cwt....	15	18	4	18

In this experiment we have an illustration of the effects of small dressings of dung and complete chemical manure separately and together. It will be observed that the small dressing of dung alone increased the yield by about 2 tons, the small dressing of complete chemical manure alone increased it by 2 tons 3¾ cwt., and the combination of the two by nearly 5 tons.

Professor Seton, of the Yorkshire College, Leeds, under whose supervision manurial experiments with swedes were carried out for the second year at four centres in Yorkshire in 1900, states the results obtained with artificials alone in the following table. The cost of the manures is given as in the official report issued by the Yorkshire College :—

Experiments with Swedes, Yorkshire, 1900.

Plot.	Manures per acre.	Cost of manure.	North Newbald (Wold).	Mirfield (Medium Loam).	Darfield Barnsley (Medium Loam).	Garforth (Clay Loam).	Average.
			YIELD PER ACRE.				
		£ s. d.	T. cwt.	T. cwt.	T. cwt.	T. cwt.	T. cwt.
1	No Manure	—	7 0	6 10	12 0	4 7	7 9
2	Superphosphate, 4 cwt. Sulph. of Ammo. 1 cwt.	1 3 1	4 13	14 15	13 15	14 0	11 16
3	Sulph. of Potash, 2 cwt. Superphosphate, 4 cwt. Sulph. of Ammo., 1 cwt.	2 4 1	16 3	16 15	16 10	15 12	16 5

It will be seen that at all the stations the heaviest crop was obtained where the chemical manure was complete. Dealing with the average yields, the use of the complete chemical manure increased the crop by 8 tons 16 cwt., at a cost of 4s. per cwt. of swedes. The omission of potash from the otherwise complete chemical manure effected a saving of one guinea in the cost of the manure, but lowered the yield of the crop by 4 tons 9 cwt.

HAY.

Potash manures are very valuable for pastures and for all hay crops, but until quite recently they have been but little used in England and Ireland for this purpose. Latterly, the numerous excellent results which have been obtained in nearly every part of the British Isles during the last few years from the use of these manures for grasses and clovers have so far convinced a large proportion of farmers and manure compounders of their great utility, nay, necessity in these times, that kainite, or one of the more concentrated potash manures, now forms a part of the dressing for these crops on a very large number of farms. Every farmer who has tried potash manure for pasture or hay crops knows that it considerably increases the bulk of hay, but it should not be forgotten that it also produces a most beneficial effect upon the

quality of the herbage. It sweetens it, checks the growth of mosses and other weeds, and increases its feeding value by the stimulus it gives to the clovers and the finer grasses.

Farmyard manure is, of course, excellent for the purpose, but usually so much of this commodity is used otherwise that very little can be spared, and as is the case with the majority of crops the most profitable return is to be obtained by using both dung and artificials.

For grass, and mixed grasses and clover, it is well known that a good dressing of nitrate of soda or sulphate of ammonia will greatly increase the weight harvested. Farmers often hesitate to use either of them because of the rank growth which sometimes results, and the increase of the coarser grasses and decrease of clover which is apt to be encouraged. It has been repeatedly proved, however, by experience that, by using kainite or other potash compound, and also phosphate in addition to the nitrogenous aliment the increase of crop may be secured without any deterioration of its quality. It may be mentioned here also that what is known as exhaustion of the soil from the use of quick acting nitrogenous manures, such as nitrate and sulphate of ammonia, takes place only when the supply of potash and phosphate, which should accompany it, has been omitted. It is the neglect of potash, and sometimes of phosphate also, which has caused nitrate to be regarded by a few as a mere whip for the soil rather than a valuable plant food, as it really is.

For pasture or mixed grasses, grown without any dung, the following formula will be found useful :—

Kainite 4 cwt., or sulphate or muriate of potash 1 cwt.
Basic slag 4 cwt., or superphosphate 2cwt.
Nitrate 2 cwt., or sulphate of ammonia $1\frac{1}{2}$ cwt.

Where dung is used half the above quantities of artificials may be found sufficient.

For clovers, sainfoin and other leguminous fodder, the main part of the nitrogenous manure may be omitted, as these plants are able to obtain the greater part of the nitrogen they require from the air.

As a source of phosphate, basic slag is seen to greatest advantage on peaty, heavy, and sour soils, and where there is a natural deficiency of lime.

The following are a few results of experiments illustrative of the use of potash manures for grass and clovers. The hay is valued at 60s. per ton.

Hay Experiments, West of Scotland Agricultural College, 1899.

Soil.	Manures Applied.			
	½ cwt. Muriate of Potash; 2 cwt. Superphosphate; ½ cwt. Nitrate of Soda; ½ cwt. Sulphate of Ammonia.		1 cwt. Muriate of Potash 2 cwt. Superphosphate; ½ cwt. Nitrate of Soda; ½ cwt. Sulphate of Ammonia.	
	Produce per acre.		Produce per acre.	
	Tons	Cwt.	Tons	Cwt.
Light Loam	1	13¾	1	17¾
Dark Loam	1	5½	1	13½
Heavy Loam	2	7½	2	15
Heavy Loam	1	12¼	1	19
Alluvial Loam	2	5	2	15
Average of five Farms ...	1	17	2	4

The average increase of hay produced by ½ cwt. muriate of potash, costing 4s. 3d., is therefore shown to be 7 cwt. per acre, an extremely satisfactory and profitable return.

Hay Experiments, West of Scotland Agricultural College, 1900.

Soil.	Manures Applied.			
	cwt. Superphosphate; cwt. Nitrate of Soda; ½ cwt. Sulphate of Ammonia.		1 cwt. Muriate of Potash; 2 cwt. Superphosphate; ½ cwt. Nitrate of Soda; ½ cwt. Sulphate of Ammonia.	
	Produce per acre.		Produce per acre.	
	Tons	Cwt.	Tons	Cwt.
Medium Loam	2	2¼	2	9¾
Light Loam	1	17½	2	1¾
Clay Loam	2	13¾	3	7½
Light Moorland	2	17¾	3	10¼
Average of four Farms ...	2	8	2	17½

Increase due to 1 cwt. muriate of potash was 9½ cwt. per acre.

The cost of the muriate of potash was 8s. 6d.

Taking the results of these two years together, in the former of which hay crops as a rule were very light, and in the latter equally heavy, it is clearly demonstrated that under extreme variations of seasons and crops, a judicious employment of potash manures is followed by a profitable increase.

With an application of six cwt. of basic slag per acre, the yield of hay obtained was 62 cwt., and when 88 lbs. sulphate of ammonia were used the yield approached 64 cwt.; but when these single

fertilizers were replaced by a mixture containing phosphates, nitrogen and potash also, the crop was increased by about 33 cwt., making a total of 95 cwt. of hay per acre.

Dr. Somerville, in detailing the results of last year's experiments in the manuring of the hay crop, writes as follows in his last annual report :—

"In the case of the first year's seeds, the 'take' of clover was an exceedingly good one, and the results furnished by the experiment clearly indicate that, under these circumstances, *nitrogenous manures must be used very sparingly, if at all.* So far as the first crop is concerned, the largest yield of all was got where the greatest quantity of nitrogen was used; but the botanical analysis shows that, of the samples investigated, that grown by the largest dose of nitrogen contained by far the least amount of clover. The nitrogen in 2½ cwt, of sulphate of ammonia, in fact, stimulated the grass at the expense of the clover, and one result of this has been that the plot which produced the biggest first crop has produced the smallest second crop. A purely mineral dressing, consisting of 4½ cwt. superphosphate and 3 cwt. of kainite per acre, produced a fair increase in the first crop (which contained a larger percentage of clover than any of the other yields), and it left the clover plants so strong in the root that the second crop, under this treatment, was the largest of the whole series. Taking both first and second crops into consideration, it has been found that the land receiving superphosphate and kainite, but no nitrogen, has given almost as large a yield as the plot receiving the same minerals, with 2½ cwt. sulphate of ammonia; and if the amount of clover, is a test of the quality of hay, the former crop should be much superior to the latter.

"It would appear, from these and other experiments, that the manuring of seeds hay is a matter that should receive very careful attention, and its character should depend upon the particular circumstances of the case. The following recommendations may be taken as a general guide :—

Poor Clover Plant: 1 to 2 cwt. sulphate of ammonia or nitrate of soda, 2 cwt. superphosphate, and 2 cwt. kainite.

'Take' of Clover, Moderate: 1 cwt. sulphate of ammonia or nitrate of soda 2 to 3 cwt. superphosphate, and as much kainite.

First-rate 'take' of Clover: 3 to 4 cwt. superphosphate, and as much kainite.,

Professor Middleton, of *the Durham College of Science, Newcastle.* in his annual report on the manurial experiments conducted by the teaching staff of the *Aberystwyth College*, assisted by *Mr. J. Alan Murray, B.Sc., Lecturer on Agricultural Chemistry*, sums up the results of his experiments in the manuring of pasture land as follows :—

"On examining the effects produced by two seasons' use ot the manures on the crops of this year, we find that in no case has nitrate of soda done much for the crop, and that over the whole twelve plots it has slightly decreased the yield. Superphosphate has on the average increased the crop, whether used alone or with other manures; it has done so most markedly when combined with kainites When so used, the profit exceeded 100 per cent.

"Kainite has produced about twice as much increase as superphosphate; it i. clear that the land requires potash manures, and that it will pay well for them. On the average of the twelve plots, the profits from an outlay of 6s. for kainite amounted to about 200 per cent., and in favourable cases rose to more than 300 per cent.

"In a favourable season, a mixture of 4 cwt. kainite and 4 cwt. superphosphate

has yielded a profit of 200 per cent., and the following mixture of manures is likely to yield a profit of at least 100 per cent. in ordinary seasons:—

2 cwt. basic slag applied in autumn.
1 cwt. superphosphate applied in spring.
4 cwt. kainite applied in spring."

Hay Experiment, Patterdown, Wilts, 1901.

This experiment was tried by *Mr. J. H. Wilcox* on a gravel soil on his own farm, and gave the following results:—

Plots	Manures per acre.	Yield per acre.	Excess from manured over unmanured plot.	Value of excess.	Cost of manure.	Net profit on manure.
		cwt.	cwt.	£ s. d.	£ s. d.	£ s. d.
1	No manure ...	27	—	—	—	—
2	Basic slag, 8 cwt.	34	7	1 1 0	1 0 0	0 1 0
3	Kainite, 6 cwt. ...	41	14	2 2 0	0 15 0	1 17 0

The great value of kainite for the hay crop is well illustrated in this experiment, in which a dressing of 6 cwt. per acre, at a cost of 15s. per acre, gave an increase of 14 cwt. of hay—*i.e.*, the extra 14 cwt. of hay was obtained at a cost of about 1s. per cwt.

The small profit obtained on the use of basic slag in this experiment was no doubt due to the dressing being too heavy for the purpose. Probably 4 cwt. per acre would have been quite sufficient to give the increase of 7 cwt. of hay, and thus yield a good profit.

Meadow Experiment in Ireland, Co. Tyrone, 1901.

The following results were obtained in six experiments conducted under the joint auspices of the *Tyrone County Council* and the *Irish Department of Agriculture and Technical Institution*, in various parts of Co. Tyrone:—

Plot.	Manures per acre.	Cost of manures.	Yield per acre. Cookstown.	Dungannon	Omagh.	Strabane.	Clogher.	Castlederg.	Average.
		£ s. d.	cwt.						cwt.
1	No manure	—	12½	23¾	30¾	40	29¼	32¾	28
2	Nitrate of soda, 1cwt. / Superphosphate, 2 ,,	0 14 6	29	33½	48½	69¼	46½	43¾	45
3	Kainite, 2 cwt. ... / Nitrate of soda, 1cwt. / Superphosphate, 2 ,,	0 19 6	37½	42¼	54¼	80¼	49¼	54½	53
4	Dung, 10 loads ...	—	20¾	31¼	46¼	68¾	44½	44	42½

It should be first noticed that—

(A) Both plots 2 and 3 at all the six stations, which received chemical manures, gave a higher yield than plot 4, which received a small dressing (10 loads) of dung.

(B) Plot 3, which received a complete chemical manure, containing potash, nitrogen and phosphate, gave the highest yield at all the six stations.

Hay Experiment. Patterdown, Wilts, 1901.

No Manure: 27 cwt. Hay.	Basic Slag, 8 cwt.: 34 cwt. Hay.	Kainite, 6 cwt.: 41 cwt. Hay.

Hay Experiment. Cornish Down, Tenby, S. Wales, 1901.

Kainite, 4 cwt. Slag, 4 cwt. } : 40 cwt. Hay.	Kainite, 4 cwt.: 36 cwt. Hay.	No. Manure: 20 cwt. Hay.

It may be well to mention that, in using the complete chemical manure, another important point is that there is no risk of exhausting the soil as when either potash or phosphate is omitted.

Dealing with the average yield of the above-mentioned six plots, it should be observed that—

(C) The yield of the plots dressed with complete chemical manure exceeded that of the unmanured plots by 25 cwt. Taking the cost of the manure at 19s. 6d., and the value of the 25 cwt. of hay as £3 15s., a profit of £2 15s. 6d. per acre is obtained on the manure used; or taking another point of view, the complete chemical manure gave 25 cwt. of hay more, at a cost of 9d. per cwt.

(D) By omitting the kainite, which supplies potash, and using only nitrate and phosphate, as many farmers are in the habit of doing, the yield was reduced by 8 cwt.; or, looking at it from another point of view, by adding 2 cwt. of kainite, costing 5s., to the manure used on plot 2, the yield was increased from 45 cwt. to 53 cwt. per acre—8 cwt. of hay more for 5s.

Hay Experiment—Cornish Town, Tenby, 1901.

This was a manurial experiment on the third crop of seed which had received a dressing of dung in February, 1900. The land is reported as medium, and in fair condition.

The manures used and the results obtained are shown in the following table :—

Plot	Manure per acre	Hay per acre	Excess from manured over unmanured plot	Value of excess	Cost of manure	Profit on manure
		cwt.	cwt.	£ s. d.	£ s. d.	£ s. d.
1	None	20	—	—	—	—
2	Kainite, 4 cwt. ...	36	16	2 8 0	0 10 0	1 18 0
3	Kainite, 4 cwt. ... Basic Slag, 4 cwt. ...	40	20	3 0 0	1 0 0	2 0 0

It will be observed that in this experiment the application of 20s. worth of kainite and slag increased the yield of hay by 1 ton, and that 10s. worth of kainite alone increased it by 16 cwt.—*i.e.*, in the first case an extra ton of hay was obtained for £1, and in the second, 16 cwt. of hay extra was produced for 10s.

Experiments with Meadow Hay—Staffordshire, 1900.

The Staffordshire County Council has recently issued a very interesting report upon experiments carried out on various soils at five centres in Staffordshire.

It is remarked initially that the soil at one of the stations was in such high condition that the manures have had but little differential effect. As such soils are very few and far between, the results obtained upon the remaining four only—which probably more nearly represent what may be expected from the use of artificial manures generally—are dealt with in the following table. The cost of manure in each case is that given in the official report :—

Plot	Manure per acre	Cost of manure per acre	Yield per acre: Burnt Wood. Strong Loam	Seabridge. Strong Clay	Blurton. Heavy Clay	Horton. Marl	Average
		£ s. d.	cwt.	cwt.	cwt.	cwt.	cwt.
1	No Manure	—	14¼	41	35	50	35
2	Nitrate of Soda, 1 cwt. ... Basic Slag, 5 cwt. ...	1 0 3	27¼	46¼	50	43	41½
3	Kainite, 5 cwt. ... Nitrate of Soda, 1 cwt. ... Basic Slag, 5 cwt. ...	1 10 0	32	56¼	55	64½	52
4	Farmyard Manure, 6 tons...	1 10 0	26¼	41	55	55	44¼

The very high yield of the unmanured plot at Horton is explained as being partly due to this plot being near a fence and on low ground. The dressing of dung on plot 4 at Horton was 12 tons per acre. Particular attention is called to the fact that the soils upon which these experiments were carried out were heavy, one is described as a heavy clay, and another as a strong clay. A glance at the table will show that kainite was very effective on all the 4 soils, including the heavy and strong clays.

It should be observed that:—

(A) At three centres out of four the complete chemical manure gave a higher yield than farmyard manure, and that the average yield from the former exceeded that from the latter by 7¾ cwt.

(B) At all the four centres the yield from the complete chemical manure of plot 3 exceeded that from plot 2 where kainite was omitted.

(C) The average yield of the plot, dressed with complete chemical manure, exceeded that of the unmanured plot by 17 cwt. of hay per acre. The cost of this manure was £1 10s., and therefore the cost of the extra 17 cwt. of hay was at the rate of 1s. 9d. per cwt.

(D) The average yield from plot 2, from the manure of which potash was omitted, was only 6½ cwt. in excess of that obtained from the unmanured plot, and this extra 6½ cwt. cost at the rate of 3s 1½d. per cwt.

LEGUMINOUS CROPS.

As above noted, potash is well known to be the "dominant manure" for the leguminosæ, which include clover, vetches, beans, peas, etc. As *nitrogen is the costliest manure* which the farmer has to buy, and as leguminous species can derive their own supplies of nitrogen from the atmosphere, actually leaving the land richer in this element than it was before, it is most important that farmers should procure as much as possible of the necessary soil-nitrogen free of cost by a development of the cultivation of leguminosæ, seeing that these are not only very valuable for feeding, but are also "nitrogen accumulators." On account of this property of direct assimilation from the atmosphere, it follows that, if there be a reasonable amount of lime compounds in the soil, the only artificial manures that require to be applied in order to ensure a first-class leguminous crop are phosphates and potash—the latter element, namely, potash, being the "dominant manure" for these plants. It so happens, however, *that the importance of potash as the*

dominant manure for leguminous crops has not been so fully demonstrated at most of the experimental stations as could be wished, the reason of that evidently being because the "dominant" character of potash as a manure for leguminous crops is now accepted on all hands as an axiomatic fact which requires no further demonstration. The ordinary farm practice of well-known agriculturists, however, is sufficient to furnish innumerable proofs of this fact, if such proofs were required. A few instances may be herewith quoted as a fair sample of the bulk.

Clover Experiments.

Sir Thomas D. Gibson Carmichael, Bart., M.P., Castlecraig, has given the results of his experience as to the advantage of a liberal dressing of potash in the growing of clover, as follows :—

"We began to use kainite eight or ten years ago, at the rate of 4 cwt. to the acre, and always applied at the time the grass seeds are sown, whether the grass seeds are sown down with the rape or with a grain crop. The practice has been first to roll the land before sowing the grass seeds; then to have a man sowing the kainite at the same time as the sowing machine was sowing the grass seeds—the one in front of the other. The land is then harrowed with light harrows, and rolled once.

"The result has been that clovers have grown on land where clovers were never seen before, and on land where a poor or middling crop of clovers used to grow there is now a good crop, and the clovers have always held in pastures, excepting in one case. This is a case, however, about which there is considerable uncertainty. The clover grew the hay year quite well, but it was not seen in the pasture. Now, the doubt in this case arises from the fact that the land got a double dose of manure, namely, 4 cwt. of kainite and 3 cwt. of sulphate of potash, and also from the other fact that the seed merchant, who supplied the seeds, was not one of the best.

"Although it would be more difficult to support it, and the opinion is therefore of less value, still we have thought that another effect of the kainite has been to stiffen the straw of the grain crop—at any rate in the year in which the kainite was applied.

"Another result undoubtedly has been that the increase of clovers has caused a rise in the general fertility of the land, and an increase in all the crops."

Experiment with Beans.

Mr. David Wilson, D.Sc., of Carbeth, Stirlingshire, Chairman of the Science Committee of the Highland Agricultural Society, stated in the course of a recent lecture at Falkirk his own knowledge as to the importance of potash as the principal manure for the bean crop, to the following effect :—

"I have grown beans for some years with various manures. The chief requirement of this crop is potash; and one can grow quite as heavy a crop with artificials as with dung. I have grown good crops with 4 cwt. superphosphate and 2 cwt. muriate of potash; but a *correspondingly larger quantity of the cheaper salts of potash seems to be equally effective.* It is better not to mix the superphosphate and

the potash salts, but to sow them separately. This dressing costs at present 27s. per acre. For the hay crop I have used for many years 3 cwt. superphosphate and 3 cwt. kainite – or proportionately less of a salt richer in potash—sown as early in the year as possible, and top-dressed with 1 cwt. nitrate of soda when growth is starting in spring This dressing encourages both clovers and grasses, and costs about 21s. per acre."

CEREALS.

The dominant manure for cereals, such as wheat, barley, oats and rye, is a nitrogenous one, but it must not be forgotten that these crops, like all the others, must also have potash and phosphate. When, however, they succeed a well matured growth of roots, clover or pasture, there is often no necessity for direct manuring. The powerful effect of nitrate of soda and sulphate of ammonia in increasing the yield of these crops is universally recognised, but the danger of lodging, or, especially in the case of barley, the risk of protracting the ripening of the grain and damaging the sample as a result of their application often prevents their use. It is well known from the results obtained in a large number of experiments in the British Isles and elsewhere, that these objectionable effects of nitrogenous manure may be neutralized, and at the same time the desired improvement secured by increasing the supply of potash and phosphate. Where a good malting sample of barley is the aim, the supply of potash should be a matter of special care, as this manure is particularly potent in improving the quality of the grain. Where there is danger of lodging, potash manure should be applied to strengthen the straw.

Where the supply of manure during previous seasons has not been very liberal, or the land is in poor condition, it will generally be found well to apply for barley 1 cwt. of muriate or sulphate of potash, 2 cwt. of superphosphate, or equivalent of other phosphate, and 1 cwt. of nitrate, or equivalent of sulphate of ammonia. In the case of oats and wheat double the above quantity of nitrogenous manure may be used with advantage on poor soils which have received but very little farmyard manure.

Oats are known to be more largely grown in Scotland and Ireland than in England. In Scotland the details of their manuring have been a subject of observation for many years, and the results obtained clearly indicate the great importance of potash. Principal Wright, who has himself superintended a large number of careful trials, addressing an assembly of farmers in December last, observed that the most suitable application for oats, according to their experimental results, was 5 cwt.

per acre of a mixture containing about 4 per cent. of ammonia, 12 per cent. soluble phosphate, and 5 per cent. potash. He also pointed out that the inclusion of phosphate and potash in the manure for oats hastened the harvest, stiffened the straw, and gave a better quality grain. The manure recommended by this authority is equivalent to about 2 cwt. of kainite, 2 cwt. of superphosphate, and 1 cwt. of nitrate of soda. On referring to some of Principal Wright's experiments on the manuring of oats in Scotland, it is found that, taking the average of four experiments, the use of 2 cwt. of kainite, costing 5s. 6d., increased the yield by 7½ bushels of oats and 3½ cwt. of straw.

In Ireland no doubt numerous experiments on oats will soon be made, and there is no reason why potash should not give in that country results equally as good as those obtained in Scotland.

The following are a few interesting particulars of manurial investigations on oats and barley.

Oat Experiments—West of Scotland Agricultural College—1897.

FARM	MANURES APPLIED				Increase produced by 2 cwt. Kainite	
	1 cwt. Nitrate of Soda; 2 cwt. Superphosphate		1 cwt. Nitrate of Soda; 2 cwt. Superphosphate; 2 cwt. Kainite			
	Produce per acre		Produce per acre			
	Grain Bushels	Straw Cwt.	Grain Bushels	Straw Cwt.	Grain Bushels	Straw Cwt.
a	31½	19¼	36¼	19¾	4¾	½
b	37½	28½	53	36¼	15½	7¾
c	46	34¾	48½	38½	2½	3¾
d	49	40½	55½	42½	6½	2
Average of 4 Farms...					7½	3½

The above figures show that on the average of four farms, the addition of 2 cwt. kainite to the manure increased the yield of grain by 7½ bushels, and of straw by 3½ cwt. per acre. The cost of producing this increase of crop was only 5s. 6d., so that the return was highly profitable.

The experiments of 1897 formed a clear and complete confirmation of those conducted during the four previous seasons, and although the applications were varied in almost every conceivable way, taking the average of seasons and soils, the conclusion ultimately arrived at was that the mixture indicated above was the best that could be employed for oats.

In some cases, even a heavier dressing of potash than that which has been recommended may prove beneficial. The soil on Crombie is a light loam, and that on Hermitage is a medium loam, and in both cases the 2 cwt. of kainite was more profitable than 1 cwt., and the 4 cwt. more profitable than 2 cwt. The results of these and other experiments have clearly indicated that potash should be included in mixtures of artificial manures for oats, not only because the potash materially increases the yield of both the grain and the straw, but because it promotes earlier ripening, as well as tending to toughen and strengthen the straw so as to make it less liable to lodge.

Dr. Somerville, in his last annual report on the Cockle Park experiments, says :—

"The profitable nature of supplying oats after lea on poor land with artificials was well exemplified in the experiment referred to. The unmanured land produced an average of only about 19 bushels per acre, whereas the use of 2½ cwt. sulphate of ammonia, 4½ cwt. superphosphate, and 3 cwt. kainite raised the average crop to 47 bushels per acre, with a corresponding increase in straw. Taking the grain and straw at a moderate rate of valuation it is found that the increase in crop has not only paid for the manure, but has left the large profit of 56s. per acre."

The *Rev. Dr. Gillespie*, who was formerly *Chairman of Directors of the Highland and Agricultural Society*, and is known all over the country as "the Minister of Agriculture for Scotland," wrote as follows in September, 1899 :—

"Ere the harvest is fully gathered in we would again call attention to the advantage and profit of top-dressing lea oats. This year the influence of the top-dressing has been most beneficial and profitable. Crops on land in poor manurial condition are light this year compared with what they are in seasons when the conditions of growth are favourable. The benefit is not derived solely from the increased yield in both straw and oats, but in the greater cleanness of the land on which the crop has been grown, and in the greater ease with which it will be cultivated and got fit for the succeeding turnip crop. For several seasons the writer has used as a top-dressing a special mixture prepared hy Messrs. Thomas Biggar & Son, Dalbeattie, with highly satisfactory results, as bulky crops, with strong well-headed plants, as it is desirable to grow, have been reaped, and the ease with which the land is pulverised and cleaned from the succeeding crop is not the least part of the advantage gained. The mixture referred to consisted of superphosphate, sulphate of ammonia and potash, which should be applied before the serial seed is sown. The sulphate of ammonia is not so liable to be lost through the natural or artificial drainage as nitrate of soda, as it becomes gradually soluble and available as the plant requires it."

Professor Campbell, of the *Yorkshire College, Leeds*, in the course of a lecture on manuring, delivered at Glasgow in December, 1899, referred to the urgent necessity for choking out the "bent" grass, which produces the "quickens," which are the most troublesome weeds met with in Scottish agriculture. On that occasion the Professor said :—

"I feel sure that if the system I have recommended for the eradication of this weed were persistently followed, bent would be less troublesome than it is at the

present time. The system that I recommend consists, first, in laying aside the common plough used for lea, and adopting a modern one, such, for example, as 'Oliver 240.' The 'bent' must be properly buried if it is to be destroyed. The second part of this system consists in applying to the lea corn such a mixture as the Scottish experiments have taught us is the best suited for the production of a large crop of corn, namely, a mixture composed of one part sulphate of ammonia, two parts superphosphate, and two parts kainite. The object is to produce a crop of corn that will choke out whatever 'bent' may have escaped destruction by the plough. The stubble after such operation will be free from weeds. There will be less cleaning to do in the spring-time, and less 'bent' will appear in the pasture. Experiments have shown us that the increase due to dressing the lea corn will fully pay for the expenditure on the manure, and thus we have clean stubbles and clean pasture without expense."

Professor Wright, in his report on the researches on oat manuring last year, states that on the average of twenty farms the most profitable plot was that manured with 88 lb. sulphate of ammonia (containing nitrogen equal to 1 cwt. nitrate of soda), 2 cwt. superphosphate, and 2 cwt. kainite. Taking the average yield of twenty farms, the Professor says that, on the plots manured as above stated, the increased value of the crop as compared with the unmanured plot was 48s. 6d. per acre, which, after deducting 20s. 6d. for manuring, left an increased profit of 28s. 6d. per acre. He remarks also: "This was the most profitable plot in our oat experiments of last year."

Barley Experiment, Nenagh, Ireland, 1901.

Capt. Wolfe, with a light loam soil on his own farm, under the auspices of the *Irish Board of Agriculture*, found the annexed cultivation results :—

Plot	Manures per acre	Yield per acre					Excess from manured over unmanured plot					Value of excess			Cost of manure			Net profit on manure		
		Grain		Straw			Grain		Straw											
		bls.	st.	t.	c.	q.	bls.	st.	t.	c.	q.	£	s.	d.	£	s.	d.	£	s.	d.
1	None	9	0	1	0	0	—		—			—			—			—		
2	Nitrate ... Superphosphate	9	6	1	0	1	0	6	0	0	1	0	6	9	0	17	3	—		
3	Kainite ... Nitrate ... Superphosphate	11	12	1	8	3	2	12	0	8	2	2	18	5	1	4	9	1	13	8

The samples of corn were valued at 14s. 6d. per barrel.

The complete manure gave a profit of £1 13s. 8d. per acre.

The omission of kainite from the otherwise complete manure caused the yield to fall to nearly that of the unmanured plot, and compared with the completely manured plot, there was a loss of £2 4s. 2d. per acre.

In another experiment tried by the same gentleman, a plot treated with a complete manure consisting of sulphate of ammonia ¾ cwt.,

superphosphate 2 cwt., and kainite 2 cwt., gave 11 barrels 4 stone of screened corn, and a total of 11 barrels 13½ stone corn per acre, whilst the yield of an adjoining unmanured plot was 8 barrels 2 stone of the former or 8 barrels 9 stone of the latter.

Barley Experiments—The Midland Agricultural and Dairy Institute, 1900.

The following statement of results obtained at Blidworth, Wilton and Muskham, in 1900, is extracted from the very interesting report edited by *Prof. Dunstan*, and issued by the Institute referred to above.

Barley—Blidworth, Notts.

The soil is a light sand, and the barley was grown after roots fed. Four varieties of the seed—viz., awnless, goldthorpe, standwell and invincible—were used for the experiment. The potash manure (kainite) gave a good result with all four descriptions. The following table illustrates its effect on the yield of the first variety, showing also the average yield of the four.

Varieties.	Manures per acre.	Yield per acre.		Excess from manured over unmanured plot.		Value of excess.	Cost of manure.	Net profit on manure.
		Grain. bus. lb.	Straw cwt.	Grain. bus. lb.	Straw. cwt.	£ s. d.	£ s. d.	£ s. d.
Awnless	None ...	31 44	14½	—	—	—	—	—
	Kainite, 3cwt.	47 8	20¼	15 20	5¾	3 4 2	0 7 6	2 16 8
Av. of 4 varieties	None ...	37 36	16	—	—	—	—	—
	Kainite, 3cwt.	44 2	19¾	6 22	3¾	1 8 8	0 7 6	1 1 2

In the above the grain is valued at 29s. per quarter, and the straw at 30s. per ton.

It will be noted, that with one variety, more than 15 bushels of barley and nearly 6 cwt. of straw were obtained by an outlay of 7s. 6d. for kainite.

Barley—Welton.

The soil in this case is a loam resting on an oolite and clay subsoil. The barley followed a heavy wheat crop, and in this case a complete chemical manure was used on two of the plots. The following table shows the effect of potash on one of the varieties grown—viz., Burton Malting.

The yield of straw is not given in the report.

Plot.	Manure per acre.	Yield per acre.	Excess from manured over unmanured plot.	Value of excess.	Cost of manure.	Net Profit on manure.
		Grain. bus. lbs.	Grain. bus. lbs.	£ s. d.	£ s. d.	£ s. d.
1	No manure ...	19 10	—	—	—	—
2	Nitrate, ¾ cwt. Superphos., 3cwt.	29 16	10 6	1 16 8	0 15 0	1 1 8
3	Kainite, 2 cwt. Nitrate, ¾ cwt. Superphos., 3cwt.	36 30	17 20	3 2 10	1 0 0	2 2 10

This experiment is a good illustration of the value of a complete manure for barley grown after wheat. As a large proportion of malting barleys are grown after wheat, particular attention is called to the results here tabulated. It is well known that the successful grower of malting barley is often very loath to use much or any manure for his barley lest the sample may be damaged. Any barley grower who has not yet tried a complete chemical manure for barley after wheat should certainly do so. If he be afraid of damaging the sample he need not manure the whole area of barley in the way recommended; but he could easily carry out the experiment on an acre, or even less.

The importance of including potash in the manure for barley may be seen by comparing the yield of plot 2 with that of plot 3. It will then be seen that the use of a complete chemical manure costing £1 increased the yield of grain by 17 bushels 20 lbs. By omitting potash (kainite) from the otherwise complete manure the cost was reduced to 15s., and the yield of grain by 7 bushels 14 lbs. Regarding the result from another point of view, 5s. worth of kainite gave 7 bushels 14 lbs. of barley.

Barley—Muskham.

Webb's Kinver Chevalier was grown on the gravel soil here after roots fed. The feeding of the roots was considered to have afforded sufficient nitrogen for a barley crop, and, therefore, no further nitrogenous manure was applied.

The chief results obtained are tabulated below :—

Manures per acre.	Yield per acre.		Excess from manured over unmanured plot.		Value of excess.	Cost of manure.	Net Profit on manure.
	Grain. bus. lbs.	Straw. cwt.	Grain. bus. lbs.	Straw. cwt.	£ s. d.	£ s. d.	£ s. d.
No manure ...	28 7	21	—	—	—	—	—
Kainite, 3 cwt.	33 42	20½	5 35	—½	1 0 0	0 7 6	0 12 6

Experiment with Wheat, Gaunts, 1900.

The results obtained in a rotation experiment on a sandy loam on *Sir Richard G. Glyn's Home Farm at Gaunts*, and reported on by the *Reading College*, should be of interest to many readers. They afford an illustration of the fact that a suitable complete chemical manure not only increases the yield of the crop for which it is specially applied, but also beneficially affects a succeeding crop. In this experiment the manures were applied for the mangold crop, and no further application was made for the succeeding crop of wheat.

Plot.	Manures per acre.	Cost per acre, 1899.	Results per acre.			
			Mangolds, 1899.	Wheat, 1900.		
				Best Tail.	Tail.	Straw,
		£ s. d.	T. cwt. lb.	qr. bus. lb.	lb.	T. cwt. lb.
1	No manure	—	17 18 64	2 6 28	108	1 7 96
2	Nitrate of soda, 2 cwt. Superphosphate, 4 cwt Kainite, 4 cwt. ... Common salt 2 cwt. ...	2 1 6	26 2 96	4 0 8	104	1 9 52
3	Nitrate of soda, 2 cwt. Basic slag, 6 cwt. ... Kainite, 4 cwt... ...	2 1 9	25 14 32	4 0 60	76	1 9 24
4	Nitrate of soda, 1½ cwt. Superphosphate, 2 cwt. Kainite, 2 cwt.... ...	1 4 1½	23 12 96	4 0 24	80	1 10 12

From this it will be seen that all the complete chemical manures not only increased the yield of the mangold crop by about 6 or 7 tons per acre and thus gave a profit, but they also increased the succeeding crop of wheat by about 10 bushels of grain and 2½ cwt. of straw.

POTASH AS A PREVENTIVE OF SCAB AND SPRAIN.

Besides being the "dominant manures" for potatoes, potash in the form of kainite serves the invaluable use of preventing "scab" and "sprain" in the plant. Apart from the true potato blight (*Phytophthora infestans*), for which the use of disease-resisting varieties of seed and a spraying with sulphate of copper are the best remedies, the main diseases which do most damage to the tuber are "scab" and "sprain." The former may be described as a skin disease, which sets up ulcer-like spots on the surface, rendering the produce unsightly, which "spoils their market." "Sprain," on the other hand, is an internal disease, which manifests itself in black bands through the centres of the tubers, rendering them unsaleable for table use. Scab is a continual source of loss to potato-

growers throughout the whole country, but "sprain" is most prevalent in the eastern midland counties of Scotland, and in the Lothians, Fifeshire and adjoining counties is often the occasion of widespread injury. Those growers, however, who regularly apply a liberal dressing of kainite to their soils are found to enjoy an enviable immunity from both "scab" and "sprain." A prominent instance of this fact may be here recorded.

Some time ago it was stated by Mr. Peter Kerr, potato merchant, Edinburgh, that Mr A. C. Brown, Pinkie Mains, Musselburgh, who is well known as the pioneer of the early potato-growing business on the East Coast, had at first found that his essays in this cultivation were seriously affected by the diseases mentioned, but, on Mr. Kerr's advice, he, later, adopted the plan of applying an annual dressing of 5 cwt. per acre of kainite, with the result that the plague was stayed. Indeed, so entirely effectual was the procedure, that Mr. Brown has for the last five years continued the growing year after year on a field which he found to be well adapted for this purpose, each successive crop of early potatoes being followed by a catch crop of grass and clover, which, after being grown in the autumn, is ploughed up in early winter and sown down with kainite-salt in preparation for the "boxed" potato seed of the following spring. In reply to an inquiry on the subject Mr. Brown has given the following statement as to his observations in this branch of agricultural practice :—

"I am very pleased to give my experience with kainite in growing potatoes. I commenced using kainite about five years ago. I have some ground which is very subject to scab. After using about 4 cwt. sown on the ploughed land during winter, I was pleased to notice that the scab had almost disappeared, and I have found it have this effect ever since. I found also that it increased the crop very much. I am convinced that it is likewise a great preventive of sprain (which has wrought such havoc among potatoes this year), as I have had no trouble with sprain wherever it was used.

"I find it is of little use if sown in spring, when the crop is being planted.

"This year I am sowing 3 cwt. and ploughing it in, and then I will sow 3 cwt. on the ploughed land and let it get incorporated with the soil.

"I also find that it gives much better results on light land than on heavy. I am convinced that if kainite had been used freely and properly last year thousands of pounds would have been saved to agriculturists on the potato and turnip crops."

KAINITE FOR THE PREVENTION OF FINGER-AND-TOE.

In the manuring of turnips, those agriculturists—and their name is legion—who are unfortunate enough to have finger-and-toe infested land, require to be very careful to avoid the use of any manurial mixtures which encourage the development of this dire pest. Every practical

farmer knows—and thousands have learnt to their sad experience—that this deformity of the roots, caused by the fungus *Plasmodiophora Brassicæ* is a lamentable scourge, which annually causes incalculable loss. With the view of finding a remedy, many of the most eminent agriculturists in the country carried out experimental work extending over years, but practically to little purpose. It became evident in general, that soil deficient in lime and potash was most liable to be infested by the parasite ; but as on the other hand, a heavy application of caustic lime had a prejudicial effect on the crops for several years after application, the scientific advisers could offer little besides the suggestion that the best means of combating the pest was to lengthen the rotation by leaving the land longer under grass. It would appear, however, that at length a scientific way of successfully resisting the pest has been discovered, as one of the results of the experimental work which has been carried on for the last four years by Lord Rosebery, at Dalmeny Park. These conclusive researches, which have throughout been conducted under the charge of Mr. John Hunter, F.I.C., F.C.S., district analyst for Mid-and West Lothian, &c., differ from all previous agricultural experiments in the fact that they are founded not on a chemical but on a biological basis. In other words, they are based on a careful study of the conditions best suited to ensure the development and beneficial action of the nitrifying bacteria and other advantageous soil organisms. Space does not permit of giving even a bare outline of the new soil-science which has been so successfully put in practice at Dalmeny, but a brief quotation from an article on the subject in the *Nineteenth Century* (November, 1899) will give some idea of the work, and will serve to show the very important part played by kainite in successfully combating the scourge of finger-and-toe. The quotation in question is as follows :—

" In the first season the beneficial results of a small dressing of ground lime were so marked that the system of applying to every field in the farm an annual dressing of 4 cwt. of lime was commenced, and has been continued ever since. In order that the small dressing should be equally distributed over the soil, Mr. Hunter procured ground lime, *i.e.*, ordinary burned lime-shells, mechanically ground to a fine state of division. At first this ground lime was applied in the compost form,but the second year's experience showed that it was equally effective and less costly when applied direct in the hot state when the land was being worked, the small quantity of hot lime applied being insufficient to injure the nitrifying and other soil organisms, besides being rapidly converted into the carbonate form when worked into the soil. It was also found that when the lime required by the nitrifying and other soil organisms was thus applied, the plots which had received their nitrogen in the form of sulphate of ammonia showed much better crops, alike as to quantity and quality, than were obtained from the plots which got their nitrogen in the form of nitrate of soda. Mineral superphosphate, supplemented in the case of the potato and root crops with fermented bones,

proved the most satisfactory form of phosphate. The Dalmeny experiments also emphasised the importance of potash for every crop, particularly the leguminous, potato and root crops. With a moderate dressing of farmyard manure, supplemented with 4 cwt. ground lime applied at the time of working the land, and followed by 4 cwt. superphosphate, 1 cwt. fermented bones, 2 cwt. of kainite, and 1 cwt. sulphate of ammonia, the Dalmeny Home Farm produces crops which are the admiration of all who see them. Another most important branch of investigation was in regard to the destructive pest of finger-and-toe in turnips, a pest which had previously baffled the skill of experimenters. The Dalmeny experimenters knew that a heavy dressing of caustic lime would kill the germs of the finger-and-toe, but it would also kill the nitrifying and other advantageous soil organisms, while, on the other hand, a small dressing of 4 cwt. per acre would be insufficient to kill the disease germ. They therefore steered a middle course so as to avoid the Scylla on the one hand and the Charybdis on the other, by applying 1 ton of ground lime per acre when the land was being ploughed in the autumn, and another ton per acre when the land was being worked in the spring. In this case they rigidly avoided the use of dissolved phosphates, and used undissolved phosphates, supplemented with 8 cwt. kainite and 1 cwt. sulphate of ammonia. This treatment proved a complete success, and the root crops grown by this system on infested soil were found to be sound and good, while those grown in the same soil under different treatment were so rotten as to be hardly worth removing. It was noted, however, that although this treatment was successful in eradicating the disease, the crop was decidedly smaller than that grown on uninfested land, to which only one-tenth of the same amount of lime had been applied. . . . When these experiments were commenced, ground lime for agricultural purposes had never been heard of, whereas now there are at least six lime works where extensive grinding 'plant' is kept hard at work to supply the ever-increasing demand for that substance."

Potash for the prevention of Clover-Sickness, Tulip-Root, and other Agricultural Pests.

Not only is potash an essential element of manure for grain and other produce, but it also serves a most important use in the prevention of the inroads of a large number of destructive insects. Thus, in her last annual report on *Injurious Insects and other Farm Pests*, Miss Ormerod (late consulting Entomologist for the Royal Agricultural Society of England) gives the following notes as to the best methods of combating the stem eelworms (*Tylenchus devastatrix*) which give rise to "clover-sickness" besides causing "tulip-root" in oats :—

"All measures, whether of treatment of the ground, or of liberal and rich manuring of a nature suited to drive on hearty growth, are of use in supporting infested plants if of material suited to its special nature, but nitrate of soda (so far as reports to myself go) has proved nearly or wholly valueless as an antidote to eelworm sickness.

"*Of special applications* for clover and oats, whether as preventives, as manure in the preparation of the land, or as dressings to bring a crop over attack, sulphate of potash alone, as a mixture with sulphate of ammonia, or both of these with phosphates, have been found most serviceable.

"Sulphate of potash at the rate of 1 cwt. per acre has had a good effect in stopping the disease and bringing a good crop; also at the rate of about ½ cwt. per acre it has done well.

"As a manurial application, a mixture of about two parts sulphate of potash, three parts sulphate of ammonia, and four parts of phosphates brought remarkably healthy plants, with few exceptions.

"A recipe found to answer well in case of attack in 'tulip-rooted oats' or 'stem-sick clover' is—sulphate of ammonia four parts, sulphate of potash one part, and steamed bones two parts; this at the rate of 1½ cwt. per acre, followed up by a dressing of 2 cwt. per acre of sulphate of ammonia.

"The following note of experiment in treatment of clover-sickness at Rothamsted, which I was kindly permitted to use, showed entirely satisfactory results:—'A mixture of sulphate of potash 3 cwt., and sulphate of ammonia 1 cwt. per acre, was applied on 3rd April.' The disease ceased, and the clover made a very vigorous growth, which was continued markedly in the second crop."

The same eminent authority, in her *Manual of Injurious Insects*, notes that a liberal dressing of kainite has been found very effective as a preventative of wireworm, which is another most destructive pest.

INFLUENCE OF MANURES ON THE PRODUCTION OF MUTTON.

During the last three years Dr. Somerville has conducted a most important and strikingly original series of inquiries at Cockle Park in reference to the part that is played by manures in the above production. The results have proved so significant that the Board of Agriculture are at present arranging to have them duplicated in various other parts of the country. The soil in the locality mentioned was poor pasture land, and the produce of the respective plots of 3 acres each, was given to fattening sheep by way of testing the comparative feeding value of different crops of grass produced by the various kinds of manurial treatment. The numerous trials disclosed a most remarkable divergence in this respect in the utility of the methods tested. In the *Board of Agriculture Journal* for December, 1899, Dr. Somerville issues a tabulated statement of details and of the inferences derived, and he shows that plot 7, manured with superphosphate and potash, showed the highest feeding value weight for weight, a very close second being afforded in plot 3, which had been treated with ½ ton of basic slag. According to the doctor's tables, the sheep fed on plot 7 (superphosphate *plus* potash) yielded an increase of 1 lb. live weight for every 20·6 lb. of hay consumed; and on plot 3 (½ ton basic slag per acre) the increase eventuating was 1 lb. live weight for every 28·8 lb. of hay consumed. In the case of all the other plots a considerably larger amount of hay was required to produce 1 lb. live weight increase; for example, in plot 2 (4 tons caustic lime per acre) no less than 30·8 lb. of hay was needed for attaining the same addition; while in the entirely unmanured plot (No. 6), the quantity of hay necessary for the purpose was 35.1 lb. In the course of his inaugural address at the opening of the first course

of agriculture and rural economy in Cambridge University, the doctor referred to these results, and said :—

"We find that it has taken pasture equal to less than 21 lb. of hay to give 1 lb. of live weight increase in the case of plot 3 (the large dressing of slag) and of plot 7 (superphosphate *plus* potash). In other words, for equal weights of herbage the feeding value of the material on plots 3 and 7 has been nearly double that which was grown on plots 2 and 6."

The more important crops only have been dealt with above, but, did space allow, the results of numerous experiments with other crops could be adduced in proof that the same statements hold good with reference to them also.

Should any reader be doubtful of the necessity of potash manures for the crops he grows, let him try for himself. It is quite easy to leave one strip of land unmanured ; to manure a second strip with a complete chemical manure, using the quantities recommended above, and to manure a third strip similarly to the second except that potash is omitted. When so arranged on strips of small area, say $\frac{1}{8}$th acre each, the eye of an experienced farmer would be able to tell him with a fair amount of accuracy whether he should use potash or not for the crop in question.

The examples we have quoted from various districts and authorities have rendered clear :—

(*a*) Some of the advantages to be gained by supplementing the yard manure of the farm with dressings of artificials.

(*b*) That, when necessary, artificials may be profitably used instead of farmyard manure.

(*c*) That, when artificials are used alone, except under special circumstances, they should form a complete manure containing potash, nitrogen and phosphate, *and that the omission of potash from the combination causes serious loss of crop and profit.*

(*d*) That where farmyard manure and artificials are used together, the latter should usually contain all the constituents of a complete manure.

The Marquis of Salisbury in 1879, said that "if farmers would manure their land with brains, as the painter mixes his paints, there would be much less heard about agricultural depression."

Sir Michael Hicks Beach in 1890 observed that "any one assisting to revive any form of agriculture is a public benefactor."

APPLICATION
of
POTASH
SALTS
in
HORTICULTURE

APPLICATION OF POTASH SALTS TO HORTICULTURE.

The great benefit to be derived from the use of potash salts in agriculture, as described in previous pages, appertains with equal truth to their applications in horticulture, especially in reference to the productiveness of orchards, and the acceleration and improvement of the growth of fruit trees and increase of their annual crops, as well as in regard to the strength and fertility of the berry-bushes which are generally placed between the trees.

It is only during the last fifteen years that serious attention seems to have been devoted to this particular line of agriculture, and the experiments which have been carried out have hardly had time to give material results, consequently less is known as to the use of potash salts in this respect.

We may safely assume, however, that trees which are being cultivated with the special object of producing a superior crop of fruit will require a different treatment, including distinct and regular feeding, as compared with those trees the object of which is only to furnish the maximum yield of wood. Admitting that more care is generally being devoted to fruit trees, little or nothing is accomplished in regard to their proper manuring, probably by reason of the difficulty in being able to obtain proper and sufficient manure at reasonable cost, the orchards being connected with ordinary farming, which latter requires all the manure the farm can produce. But even here artificial manure can be applied to the greatest advantage.

The essential substances required for the feeding of fruit trees and allied cultivations are the same as those necessary for all other kinds of vegetable life, and consist of lime, potash, nitrate and phosphate, all of which must be supplied in proper and soluble proportions.

The average quantities required for fruit trees in general are as follows :—

Lime	...	...	...	$1\frac{3}{4}$ cwt.	per acre.
Potash	...	...	...	$1\frac{1}{3}$,,	,,
Nitrate		...	...	$\frac{3}{4}$,,	,,
Phosphate		...	...	$1\frac{1}{4}$,,	,,

Lime, it will be seen, is demanded in the largest quantity, principally as a constant feeder and improver of the soil.

Potash plays an important part not only in the growth of wood and foliage, in the formation of blossom and fruit, but also in the improvement of the single fruit in regard to size, colour, taste and aroma. Trees which have been manured with potash salts are also less liable to suffer from frost.

Phosphate will produce an earlier and greater crop, thus increasing the fruit-bearing capacity of the tree.

The mere manuring with potash and phosphate, however, can only be satisfactory for old and strong growing trees, while the presence of

Nitrate, in its proper proportions, is necessary for the satisfactory growth of new planted and young trees.

The quantity, as well as the kind of manure to be used is naturally dependent upon the quality of the soil and the species of fruit that is grown, but there is no reason why proper manuring, applied to horticulture, should not be as easy and give the same satisfactory results as are obtained in agriculture. Although it is not possible to give a general rule suitable for all purposes, the following statement, giving the minimum and maximum of the quantities of manure required, may serve as a guide :—

Artificial Manure Required Annually per Acre.

Muriate or sulphate of potash } $1\frac{3}{4}$ to $2\frac{2}{3}$ cwt.

Or for sandy soil, 7 to 10 cwt. kainite.

Two to $3\frac{1}{4}$ cwt. of potash manure salts (40 per cent.) may be substituted for the muriate.

Potash alone cannot produce a proper result; therefore, the simultaneous supply of phosphate and nitrate is necessary.

The phosphate can be supplied in form of

Superphosphate	$2\frac{2}{3}$ to 4 cwt., or
Basic slag	3 to $4\frac{2}{3}$ „ or
Bone manure...	3 to $4\frac{1}{4}$ „

The phosphates and alkaline salts are mixed, spread out over the field and ploughed down.

As soon as the sap is beginning to rise into the trees, nitrate should be supplied to the soil, generally half or two-thirds of the total quantity required, the balance being distributed either before the bloom or as soon as the fruit is formed, the ripening of the latter being thereby greatly accelerated. The supply of nitrate should also be regulated in such way that those trees which show a great growth of wood and little fruit should be sparingly manured, whilst others with weak growth and great crop of fruit should be provided with more manure.

The quantity of nitrate required would be—

Nitrate of soda, 2 to $4\frac{1}{4}$ cwt., or
Sulphate of ammonia, $1\frac{3}{4}$ to $3\frac{1}{2}$ cwt.

Rich soils, and those which are dressed with farm manure every third or fourth year, need a smaller quantity of other fertilizer, whilst soils poor in nutriment, which is easily recognised by the slow growth, early falling off, and defective ripening of the fruit, want a larger proportion of the addition. The first time a soil receives artificial manure, a more plentiful dose, say 1½ times the quantity, should be given.

Results from the orchards belonging to Freiherr von Oldershausen, Feldbrunnen, at Osterode a. Harz, Germany, will afford a striking proof of what can be obtained in a short space of time with proper potash manuring.

APPLES.

An experiment in 1901 with the variety of apple known as "Granensteiner," on 11 years old trees, gave as a first crop, "per tree"—

With manure, 29 apples = 6.3 lb.
No manure, 6 apples = 1.1 lb.

The kind of apples known as "Winter-Goldparmäne" had already, in 1895, given a good crop, which, however, was destroyed by hail. The trees as well as their branches were much damaged, and required a long time to get into normal state again, but this period was visibly shortened in those trees which had had the benefit of potash manure.

Manure Experiment with "Winter-Goldparmäne."
Feldbrunnen, 1898–1901.

Manures per Tree	Average yield per tree in lbs.			
	1898	1900	1901	Total of 3 crops
No manure	9.36	14.6	3.60	27.56
Jauche (mud water)	4.82	15.2	21.60	41.62
Manure, with potash: 1.4 lb. chloride of potash, 1.5 lb. basic slag, 1.0 lb. sulphate of ammonia	5.60	24.6	18.24	48.44
Manure, without potash: 3.5 lb. basic slag, 1.0 lb. sulphate of ammonia	6.12	11.8	8.24	26.16

The crop from the trees on the unmanured part of the orchard was delayed by a hail-storm, and the feeding stuff still remaining from the earlier manuring explains the great crop obtained in 1898.

The next year's formation of the fruit was destroyed by frost, and the following crop in 1900 was considerably greater upon all parts, while the benefit from the potash manuring was visible, not only in the superior quality of the fruit, but also in the increased quantity.

Manure Experiment with "Winter-Goldparmäne," 1900.
The crop being divided into three qualities.

Manure per Tree.	Average Yield of Apples from five Trees, in lbs.			
	I. Quality.	II. Quality.	III. Quality.	Total in lbs.
No manure	25.0	45.0	5.0	75
Jauche (mud water)	18.0	46.0	12.0	76
Manure, with potash ... ... 1.4 lb. chloride of potash 3.5 lb. basic slag 1.0 lb. sulph. of ammonia	28.0	8.3	12.0	123
Manure, without potash ... 3.5 lb. basic slag ... ... 1.0 lb. sulph. of ammonia...	8.0	34,0	17.0	59

The potash manure increased the number as well as the size of the apples ; the preponderance of the first quality is of importance, as it fetched about $1\frac{1}{2}$ times as high a price as the inferior sorts. The apples thus cultivated at Feldbrunnen were of the best description in the market.

CHERRIES.

Sweet cherries, strange to say, have been so far a failure at Feldbrunnen, the reason being, perhaps, that the climate is not suitable. Similar trees of the ordinary sour kinds have, on the other hand, succeeded much better, and the extra cost of manure has been richly repaid by the increased and far superior product.

The average yield during the last three years has been as follows :—

Manure Experiment with Cherries, Feldbrunnen, 1899–1901.

Manure per Tree	Average yield per Tree in lbs.		
	1899	1900	1901
No manure	2.72	8.66	5.8
Jauche (mud water)	4.50	10.08	10.12
Manure, with potash: 1.4 lb. chloride of potash 3.5 lb. superphosphate 2.0 lb. sulphate of ammonia	8.02	14.56	18.64
Manure, without potash: 3.5 lb. superphosphate 2.0 lb. sulphate of ammonia	2.46	10.32	10.80

PLUMS.

A portion of the experimental farm at Leopoldshall was reserved in 1893 for the culture of plums, for the purpose of ascertaining the effect of various methods of stimulation.

Manure Experiment with Plums. E. Lierke, Leopoldshall.

"Victoria Plum Trees," planted in 1893.

Manure per Tree	Average yield per Tree in lbs.							Excess Yield from Manured over Unmanured Plot		Cost of manure for 9 years	Net profit
	1896	1897	1898	1899	1900	1901	Total of 6 crops	Weight lb.	Value at $1\frac{1}{2}$d. per lb.		£ s. d.
No manure	0.62	1.00	3.26	0.85	1.40	3.44	10.57	—	—	—	—
Manure, with Potash: 1–1.4 lb. sulphate of potash; 1.5–2.0 lb. superphosphate; 1.0–1.5 lb. sulphate of ammonia	0.77	4.48	8.61	7.27	27.85	20.31	69.29	58.72	0 7 4	0 3 0	0 4 4
Manure, without potash: 1.5–2.0 lb. superphosphate; 1.0–1.5 lb. sulphate of ammonia	—	2.07	6.84	3.79	6.30	14.60	33.60	23.03	0 3 4	0 1 10	0 1 6

From the above table it will be seen that the crops during six years, obtained from trees manured with potash, gave a yield of 58.7 lb. in excess of that obtained from trees on unmanured soil, the value of which, at $1\frac{1}{2}$d. per lb., amounted to 7s. 4d., at an extra cost for manure of 4d. per year for each tree during nine years, equal to 3s., leaving thus a net profit of 4s. 4d. per crop from each tree.

Without potash the yield sank to 23 lb., representing a value of 3s. 4d., whilst the cost of the manure per tree was reduced by $2\frac{1}{2}$d., leaving a net profit of 1s. 6d. only.

The influence of the different management upon the growth of the trees has been very marked, since those that had the benefit of the potash manifested a considerable increase, not only in the growth of the wood, but also in the crown, when compared with trees which had received the other manure, and still more with those that had no artificial assistance.

GOOSEBERRIES.

The planting of berries in conjunction with fruit trees in orchards has proved to be of great advantage, as in this way the berries gathered not only cover all expenses of keeping the soil in proper cultivation from the very beginning, even before the fruit trees reach the age of bearing, but allow moreover, of enough profit for defraying the expenses of rent. A profitable outcome can also be sooner attained, and with greater ease, by suitable use of potash salts, as was clearly demonstrated during eight years' careful observation on the Leopoldshall Farm. Gooseberries, especially, are proved to demand an unusually copious feeding with artificial manure. In the course of six years' cultivation of this plant, half the crop was picked off, half left to ripen, the berries of the size of hazel nuts being used for cooking, after which the remaining fruit improved materially, and furnished a considerable crop of ripe berries of great weight and high market value.

Manure Experiment with Gooseberries. E. Lierke, Leopoldshall.

"Jolly Angler," planted 1894.

Annual manuring per 1 ar. (=100 square yards).	Average yield from 1 shrub, in grammes(=15.4323 grains).							Total yield from 7 crops, in kilos.	
	1895	1896	1897	1898	1899	1900	1901	From 1 shrub, Kilo.	From 1 ar. 42 shrubs, Kilo.
A.—Yield from unripe berries.									
No manure	5	9	16	53	129	226	204	0.642	27.0
Manure with potash— 6 lb. potassium chloride ... ... 6.80 lb. superphosphate ... ... 6.00 lb. sulphate of ammonia	11	19	59	29	445	310	525	1.398	58.7
Manure without potash— ... . 6.80 lb. superphosphates ... ... 6.00 lb. sulphate of ammonia	1	30	26	65	141	253	351	0.867	36.4
B.—Yield of ripe berries.									
No manure	30	71	268	457	611	487	955	2.879	120.9
Manure with potash— 6 lb. potassium chloride ... ... 6-80 lb. superphosphate ... ... 6.00 lb. sulphate of ammonia	82	219	558	283	1,796	1,174	2,402	6.514	273.6
Manure without potash— 6.80 lb. superphosphate ... ... 6.00 lb. sulphate of ammonia	24	127	260	584	628	519	1,147	3.289	138.1

The results obtained from the cultivation of the kind known as "Jolly Angler," are shown in the above table. The crop of green unripe gooseberries obtained by potash manuring has doubled, whilst that of the ripe berries increased more than four times; without potash, in spite of heavy applications of phosphate and nitrate, the yield scarcely exceeded that of a wholly unaided soil.

In addition to the effect of the saline treatment on the aggregate weight, the single berries were also larger and improved in flavour. We append some figures showing the improvement accruing as regards size :—

Manure.	Average weight of 1 berry in grammes (=15.4323. grains).							Total average weight.
	1895.	1896.	1897.	1898.	1899.	1900.	1901.	
No manure ...	2.7	5.7	5.6	7.6	7.5	5.4	5.6	5.7
With potash	5.1	10.8	11.4	11.4	13.2	10.1	10.4	10.3
Without potash	3.0	7.0	6.3	7.5	7.9	6.2	6.1	6.3
	Increase from potash manuring							4·0 gramme

Estimating the value of the crop obtained on 1 ar. (=100 square yards) at 30 pfennige (=3d.) per kilo (=2.2 lb.) for the unripe, and at 50 pfennige per kilo for the ripe gooseberries, the following table will show the results :—

Manure.	Yield from 1 ar.		Excess from manured over unmanured soil.			Cost of manure in marks.	Net profit in marks.
	Berries.		Berries.		Value in marks (shillings).		
	Unripe.	Ripe.	Unripe.	Ripe.			
	Kilo.	Kilo.	Kilo.	Kilo.			
No manure ...	27	120.9	—	—	—	—	—
With potash	58.7	273.6	31.7	152.7	85.86	11.52	74.34
Without potash	36.4	138.1	9.4	17.2	11.42	7.68	3.74

By means of potash manuring an excess value of 85·86 marks was obtained, which, after deducting the cost of the manure during the eight years, leaves a net profit of 74·34 marks, equal to 9·29 marks per year. The addition of phosphate and nitrate alone to the stable manure seems not to have produced any benefit, as the excess yield sank to 11·42 marks and the profit to 3·74 marks, equal to only 0·47 marks per year.

STRAWBERRIES.

The cultivation of this fruit requires more careful and expensive attention, but nevertheless a satisfactory and highly remunerative result is obtained as early as the second year after the setting of the plants. In addition to stable manure, which will give a general improvement to the soil and should always be applied before setting the plants, and be repeated later as a protection for them during the first winter after their planting, artificial manure should be given in supplement, especially potash and phosphates.

The experiments with "Laxton's Noble" and "King Albert of Saxony" varieties, the results of which are summarized in the following tables, render it clear that the same lessons apply to this as to other fruits :—

Manure Experiments with Strawberries

E. Lierke, Leopoldshall, Stassfurt.

"Laxton's Noble," planted 16th and 29th July, 1895.

Dress-row beds, with 536 plants on 100 sq. yards plot.

Manure for 100 sq. yards, in addition to 500 kilo stable manure before setting the plants	Yield from 100 sq. yards Average from 2 plots of land				Excess from manured over unmanured plot		Cost of manure in marks	Net profit in marks
	1896 kilo	1897 kilo	1898 kilo	Total kilo	Weight in kilo	Value 1 kilo at 0.6 marks		
No manure	15.5	106.9	99.2	221.6	—	—	—	—
Manure, with potash: 1896 1897 1898 3.0–2.0–2.0 kg. chloride of potash ... 3.4–3.4–3.4 kg. superphosphate ... 1.5–2.0–2.5 kg. sulphate ammonia...	27.0	123.7	126.2	273.9	52.3	31.38	3 44	27.94
Manure, without potash: 1896 1897 1898 3.4–3.4–3.4 kg. superphosphate ... 1.5–2.0–2.5 kg. sulphate ammonia...	17.7	116.0	93.1	226.8	5.2	3.12	2.32	0.80

Manure Experiment with Strawberries.

E. Lierke, Leopoldshall, Stassfurt.

" Goschke's König Albert von Sachsen," planted 1896.

Dress-row beds, with 536 plants on 100 square yards.

In 1899 one row was removed, leaving 417 plants.

Manure for 100 sq. yards, in addition to 500 kilo stable manure, before setting the plants.	Yield from 100 sq. yards. Average from 2 plots of land.				Excess from manured over unmanured plot.		Cost of manure in marks.	Net profit in marks.
	1897.	1898.	1899.	Total in kilo.	Weight in kilo.	Value. 1 kg. at 0·6 marks.		
No manure	84·4	143·1	73·1	300·6	—	—	—	—
Manure with potash 1897 1898 1899 3·0–3·0–3·0 kg. chloride of potash ... 2·0 — 5·0 kg. basic slag 2·0–3·0–3·0 kg. sulph. of ammonia...	97·7	174·7	89·7	362·1	61·5	36·90	4·09	31·81
Manure without potash 1897 1898 1899 8·0 — 5·0 kg. basic slag 2·0–3·0–3·0 kg. sulph. of ammonia...	92·6	155·0	60·9	308·5	7·9	4·74	2·65	2·09

VINEYARDS.

An addition of artificial manure to the usual dressing has been found to pay well. It is the practical experience of vine growers that the quantity of potash, nitrogen and phosphoric acid applied must by far exceed the usual amount of farmyard manure, if the vineyard is to be brought to, and kept in a healthy, strong, and fruitful condition, and to yield a maximum return.

Want of space prevents us from giving instances of the benefit accruing to garden flowers, to evergreens and shrubberies by a judicious use of potash manures.

STEAM
POWER
PLANTS.

General Remarks

ON

ENGINES AND BOILERS.

Steam Power Plants.

It is often very difficult to decide what type of power machinery should be selected for a plant, yet this is a question of the highest importance to the prospective steam user. A few general remarks may, therefore, be in order, so much the more because, in a great number of cases, the manager in charge of a large concern, while keeping account of his coal bills, knows next to nothing of the power produced, or whether the cost of each horse-power developed is within the proper amount or several times what it should be. He knows that he is paying exactly so much per year for his power; but, too often adopts no measures to ascertain whether this amount could or should be reduced.

Engines.

The economy of different types of engines varies very greatly, so that while the plain slide-valve engine of to day requires six pounds of coal or more per hour to produce one horse-power, the best modern triple and quadruple expansion engines accomplish the same result with one and a quarter pounds. Generally, however, the choice does not lie between such extreme types, but nowadays rather between, say, a plain Corliss engine, producing a horse-power under fair, every-day working conditions, at the expenditure of about three pounds of coal per hour, and a first-class compound condensing Corliss, doing the same work with two pounds of coal; or saving one pound per hour for every horse-power developed. Assuming that this engine runs 300 days in the year and only ten hours per day, the saving is nearly one and a half tons of coal per year for every horse-power. With coal at 10s. per ton, the total expense per ton for handling of coal and ashes brings the actual cost up to not less than 14s. per ton. One pound per hour will therefore cost £1 1s. per year. The total difference in the cost per horse-power of these two engines installed in place will, as a rule, not exceed £4 10s., so £1 1s. per year represents an interest of about 23 per cent. on the investment. This saving is more than doubled in cases where the engine is run night and day. In a plant of several hundred horse-power the saving becomes of such importance, that it may determine success. The estimate is put at a low figure, and

it must be remembered that the avoidance of negligence on the part of the man in charge of the plant will proportionately make the actual economy still greater.

Furthermore very frequently the more efficient plant, taken as a whole, will be little, if at all, higher in cost than one supposed to be so much cheaper. This is due to the fact that the more economical engine, consuming less steam, will permit a reduction in boiler capacity, and the saving thus effected, with the reduction in the size of the buildings required for housing, will often go far toward paying for the higher first cost of the engine itself. The economy also runs right through the plant in all its parts, such as piping, feed-pumps, heaters, etc., which must be considered as a whole in forming an intelligent estimate as to the real difference in cost of the complete machinery. It will then be evident that a high-class plant will generally result in a total saving of not less than from 40 to 80 per cent. on the extra investment, frequently, in fact, saving the whole extra cost in less than a year.

And yet there are many conditions under which it would be folly to instal such high-grade apparatus. This is specially the case when the plant is of a temporary nature, or when the work is of an intermittent character. In other cases, again, it is of paramount importance that the machinery be of the greatest possible simplicity, and economy of running then becomes a question of only secondary consideration.

After having decided upon the general type and grade of engines that will be most suitable for the undertaking in view, it still remains to be determined whether the engines are to be of the horizontal or of the vertical make. The former type would unhesitatingly be recommended, except where vertical engines become an absolute necessity on account of limited space, or where the size of each unit runs up to several thousand horse-power. This is contrary to the idea that vertical are more economical than horizontal engines. However, to-day the friction of a properly designed horizontal engine does not exceed from 6 to 8 per cent. of the rated power, and only a small fraction of this loss can be saved by using vertical engines. Such a saving is dearly paid for ; because, not only does a vertical engine cost more money to buy, but, being less accessible, it receives less care from its attendants, and the repair cost is, therefore, invariably much higher than in the case of a horizontal engine.

Of late years the steam jacketing of cylinders of compound and

multiple expansion engines has become more and more the rule, resulting in a saving of fuel averaging fully 10 per cent. The additional first cost is but a trifle, and no plant can be considered quite up to date where the cylinders are not thoroughly jacketed with steam.

The total gain in expense that may be expected from jacketing varies somewhat according to conditions; but, as a general rule, steam jackets on compound or triple expansion condensing engines may be relied upon to effect a saving of from 8 to 12 per cent. It has, furthermore, been found that the best results are obtained when all the cylinders are jacketed; also, that it is of more importance to jacket the low pressure cylinder than the high pressure, the relative value being about as 7 to 3.

It is essential, however, that the jackets be kept thoroughly drained, since, if they are allowed to fill with water, they will beeome a source of loss, instead of profit. This draining is generally accomplished by means of steam traps, which eject only the water condensation, and it is necessary that these traps should be carefully looked after to make sure of their proper performance of the work they are intended to do.

To still further insure dry jackets, it is now the practice to utilize the jacket steam for driving the independent air pump. The same steam is caused to pass through all the jackets in succession, and a lively circulation is set up, which materially increases their efficiency.

Boilers.

The difference in economy, under test conditions, between the best types of boilers is very slight, yet the daily working cost may vary to a considerable extent, and it is, therefore, equally as important to select the right kind of boiler for the service as it is to pick out the most suitable engine.

Much depends upon the nature of the feed water. The harder the feed water, or the more mud it contains, the greater the importance of selecting a boiler that is not only accessible for the removal of scale after it is formed, but also constructed so that as little scale as possible may adhere to the heating surfaces. Any scale formed will reduce the economy as well as the capacity of the boiler plant; scale is, therefore, a source of constant loss which, however, does not become apparent during an initial test made with a clean boiler.

The kind of fuel that will be used is another important factor in determining the type of boiler. In anthracite regions it is necessary to have a very large grate surface, while, on the other hand, the short flame ot anthracite coal permits the use of boilers having a comparatively low fire-box. With such coals it is also practicable to allow the gases to come in contact with the tubes very shortly after leaving the grate; while with all kinds of soft coals or wood, the fire-box must be high and the flame given a long, free sweep, in order to secure the best economy, as well as smokeless combustion.

The size of the installation must also be taken into account, since, for large plants economy of space becomes a very important consideration. For great total power, large units become a necessity, in order to keep the size of the plant within due bounds.

The choice of type depends, also, largely upon the steam pressure which is to be carried, and this, in its turn, depends upon the kind of engine that will be used. Steam pressures have been steadily advancing during the past thirty years, until to-day few plants of any size use steam of less than 120 pounds pressure per square inch, while 180 pounds and higher pressures are by no means uncommon. For compound engines very little is to be gained by exceeding 120 pounds pressure, because, while the economy will be improved by using pressures as high as 150 pounds, the difficulties of keeping the piping tight and other parts in good working order, on the other hand, very materially increase. Ordinary horizontal return tubular boilers are very well adapted to carry pressures up to 125 pounds per square inch; but for higher pressures, or for large units, special forms become a necessity.

Another consideration is the nature of the service the boiler is to perform. While most boilers are good enough for steady work, it is not so easy to secure a boiler that will answer to a sudden demand for extra power, as in electric power plants, hoisting plants, &c. For such situations it becomes indispensable to use a boiler with a large reserve capacity of water, otherwise the steam furnished will be extremely wet when the engine is called upon to suddenly develop a large excess of power.

Accessories.

Steam users frequently select a high-class engine and, perhaps, first-class boilers to furnish the steam, and then apply no special consideration as to efficiency in purchasing the accessories that go

to complete the plant. Yet it is possible to waste as much steam by using improper pumps, poorly designed piping, &c., as can be saved by the most economical engine.

Another matter that seldom receives the consideration it deserves is the question " Whether it is advisable to make a plant condensing or non-condensing." The difference in cost is very slight, due to the fact that for plants running condensing, much less boiler capacity is required ; indeed, except for very small installations, the condensing plant becomes the cheaper in first cost. The only really vital question is whether or not cooling water in sufficient quantity can be obtained. To-day even lack of water is often no serious obstacle to condensing, for it is now possible to so cool the water that it may be used over and over again with but very slight loss. Condensation does not only result in a direct saving of fuel, but, by means of it, compounding often becomes possible even where the load is so variable that nothing but plain engines would otherwise have given satisfaction. Triple and quadruple expansion are entirely out of the question unless condensers are used. To derive any benefit from condensation it is, however, necessary, first—to obtain a good vacuum; second—not to waste more steam in producing this vacuum than corresponds to the advantage resulting from it.

Condensers.

The question as to whether it will be better to use a jet condenser or a surface condenser is one which must be specially considered for each individual case. As a general rule, however, a surface condenser is indispensable in all cases where the feed water is bad and in its natural state unsuitable for use in the boilers. The condensed steam from a surface condenser is not wasted, but is, in the form of distilled water. pumped back into the boilers.

Since, however, the oil used for cylinder lubrication is carried over with the exhaust steam, care must be taken that only as little as possible be used and that it is of first-class quality. Any oil entering the boilers is injurious, and even a comparatively small quantity of an unsuitable sort may entirely ruin the boilers in a short time. It will invariably be found that the best grades in practice are the cheapest to use, owing to the smaller quantity required. Oil separators, placed in the exhaust piping, often prove advantageous, as also filters for separating the oil from the feed water. Where the feed water is

pure, jet condensers instead of surface ones may be used at a considerably lower first cost. In many cases the jet condensers will answer equally well, and they are free from the objection raised, *i.e.*, contamination of feed water by oil.

Air Pumps.

A very common form of air pump for condensers is the direct-acting type, either horizontal or vertical. Its chief recommendation is its low first cost, yet a very little calculation will show that this class of air pump leads to an excessive waste of fuel. Assume an ordinary compound Corliss engine to be installed, which, condensing, will use about 14½ pounds of steam per horse-power per hour. The power required to drive the air pump is only about 1.2 per cent. of the engine power, but a direct acting air pump consumes not less than 200 pounds of steam for each horse-power needed to operate it. In other words, an independent direct-acting air pump would increase the total steam consumption of the plant by an amount equal to fully 16 per cent. of the steam required for the main engine. This is about four times as much as an ordinary crank and fly wheel air pump will consume. The waste of this magnitude necessitates a corresponding increase in size of the boiler plant, which will more than offset the higher cost of the air pump.

A properly designed crank and fly wheel air pump will, furthermore, give from one to two inches better vacuum than a direct acting pump, thus resulting in a corresponding saving in fuel.

The amount of condensing water required for a plant depends upon the economy of the engine as well as upon the temperature of the water. Generally speaking, from three-quarters of a gallon to one gallon of water per minute is sufficient for each horse-power developed and wherever such a supply can be obtained it will nearly always be found advantageous to condense. In some localities where the water supply is scant, it is possible to conduct the water from the condenser to a cooling pond, where its temperature is sufficiently lowered to permit of its being used again. This can generally be done very cheaply where it can be done at all. Other means of cooling consist of long troughs, or of tower-like structures, with or without fans for supplying a current of air. With the above-mentioned cooling methods the total loss of water due to evaporation is, as a rule, less than an amount equal

to the feed water, which otherwise would have to be supplied; therefore with such systems the quantity of water need not enter into consideration.

Feed Water Heaters.

Feed water heaters are now in universal use, and no steam plant is complete without them. Often a single heater is all that is required, but there are cases where a much greater economy can be obtained by using two heaters in a series. This latter is especially true for condensing plants, in which the latest practice consists of first giving the feed water a preliminary heating in a large heater, located so that the exhaust steam from the main engine passes through it on its way to the condenser; in this heater the temperature of the feed water is raised to about 120 degrees. From there the feed water passes to a second heater, into which all the auxiliary engines, such as feed pumps and air pumps, exhaust. Under these circumstances the auxiliaries are run non-condensing, and by means of this expedient feed water at a temperature above 200 deg. Fahr. is made possible in condensing plants, this resulting in an economy which very much more than counter-balances the slight loss due to running the auxiliary machinery non-condensing. Care must, of course, be exercised to so design the latter that their steam-consumption will not be unduly in excess of that required to heat the feed water.

Piping.

The steam and exhaust piping of a steam plant must be arranged to prevent loss of pressure, as well as that due to radiation. Elbows and turns should be avoided. and yet the piping must not be so straight as to be stiff and unyielding. Drop in pressure in the steam pipe is effectually counteracted by the use of a receiver and separator.

Loss due to back-pressure resulting from the passage through a heater is often overcome by introducing a suitable by-pass, small enough to insure that a sufficient proportion of the steam shall enter the heater.

It is now the rule to protect by non-conducting coatings all steam piping, feed water heaters and tubes and in the best practice the covering for large pipes is put on three inches thick, thereby reducing to a minimum the loss from condensation.

Free Exhaust Valves.

A desirable plan is to arrange the pipes of condensing plants so that the engine may be run non-condensing in case the condenser should be out of order. Under such circumstances a self-acting free exhaust valve is preferable. These are so constructed that they automatically open whenever the pressure in the exhaust piping exceeds that of the atmosphere, and close again when a vacuum has been restored.

Steam Traps.

Notwithstanding the greatest care in covering, there is a constant condensation in steam piping, receiver, &c., and the condensed water must be removed by properly constructed drains, which with great advantage may be fitted with automatic steam traps, so that only the water of condensation will be removed and that no loss of steam will take place.

It is usual to convey all this water to a hot well, from which it is pumped back to the boilers. These hot wells are often provided with their own independent pumps, arranged so as to automatically remove the water as soon as a sufficient quantity has accumulated.

Lubrication.

The question of oiling seldom receives the thought it deserves ; a plant is supposed to be properly lubricated so long as it runs without undue heating of bearings and subsequent stoppage, and yet a good deal of money may be saved or wasted according to the methods and materials employed for this purpose. By the use of unsuitable lubricants it is easily possible to create an abnormally high expense account, for both oil and fuel, the latter being due to the loss of power resulting from increased friction, and this item, while less apparent, is often several times more serious than the mere cost of oil. The power wasted in friction even in the best designed plants is never less than 15 per cent. and generally averages 25 to 30 per cent. Even this friction is very often doubled by using the wrong lubricant, so that frequently 25 to 30 per cent. of all the fuel used could be saved by a simple change of oil.

As a general rule the higher priced oils are so much more efficient that the reduced quantity required more than compensates for the

increased cost per gallon, to say nothing of the saving in power effected. But price alone is no guide to the selection of oil of the proper grade; heavy oils must be used for heavy pressures, while for light, fast-running machinery, a lighter oil is necessary.

In order to still further reduce the expense of lubrication, automatic oiling systems have been devised. The simplest of these is the gravity system, in which all the oil is pumped into an overhead tank, from which it is, by means of a system of piping, conducted to the oil cups on the bearings. Having once served its purpose as a lubricant the waste oil is collected and pumped back to the overhead tank, being filtered on its way. In this manner only about one-quarter the quantity of oil that would be needed with an ordinary hand feed, is used, and better lubrication is secured.

Many persons have an idea that high-class materials and design have their place only in nicely finished plants, but a little thought will soon prove that they are as essential to the roughest class of mining machinery as to a "show" power station in the heart of a large city. The outward finish and polish may vary, but the durability, reliability and efficiency of each plant depends entirely upon the care with which each part has been designed and fitted, as well as upon the quality of the raw materials entering into its construction. As a matter of fact, there are few, if any, applications of machinery where the service required from it is harder and more continuous than in mining and metallurgical plants, or where an enforced stoppage will result in a greater loss of money.

Continuous running, for long periods of time, is possible only when the machinery in all its details has been made with scrupulous care, especially in regard to its working surfaces and the strength of its different parts. A break-down will often cause a stoppage more expensive than the whole cost of the machine to which the accident has happened.

AIR COMPRESSORS.

AIR COMPRESSORS.

In the selection of an air compressor for permanent service, the economy with which it will perform its work should receive attention, It is important, first of all, that the air cylinder be the most perfect yet devised, and, second, that the steam engine be capable of developing the power required, at the least cost, both for operation and for maintenance, What is indisputably best for the stationary engine is equally best if that engine be the motor part of an air compressor.

The Corliss Engine, invented in 1849, was at once demonstrated to be the most economical type of steam engine for large permanent plants, and after the lapse of nearly a half century, though practically unchanged in general construction, it is without a rival, the standard motive power for mining, manufacturing, or electrical work, where profits are contingent upon low cost of operation.

The best type of Corliss Engine forms, in combination with an Ingersoll-Sergeant Piston Inlet Air Cylinder, the most perfect and economical air compressor.

The first cost of such a compressor is, of course, higher than that of less economical machines. This difference in the first cost of the compressor is, however, largely offset by the difference, in the reverse way, in the cost of the boilers required; the "cheap" compressor often requiring double the boiler capacity to enable it to accomplish an equal work of compression. But with the slight additional first cost comes a saving of fuel so great and striking, that the Corliss Compressor is rapidly monopolizing the field for large and permanent plants everywhere. Besides its economy in fuel, no design of engine is less subject to breakdowns, costs so little for repairs, or requires so little attention from a competent engineer. It is not an uncommon record for such an engine to run economically for years without any expense for the renewal of parts.

Since the introduction of the Corliss the consumption of water per horse power per hour has been reduced to as small an amount as twelve and one-half pounds, while the earlier engines not infrequently required as much as sixty to seventy-five pounds; a gain of over eighty per cent. While much of the saving is due to be a better understanding of the laws of transmission of heat, and its conversion into power, a large proportion of it was made possible by the invention of the Corliss features.

Fig. 16. Direct-Acting Steam-Driven Tandem Air Compressor.

(Schram's Patent.)

By Messrs. Richard Schram & Co., London.

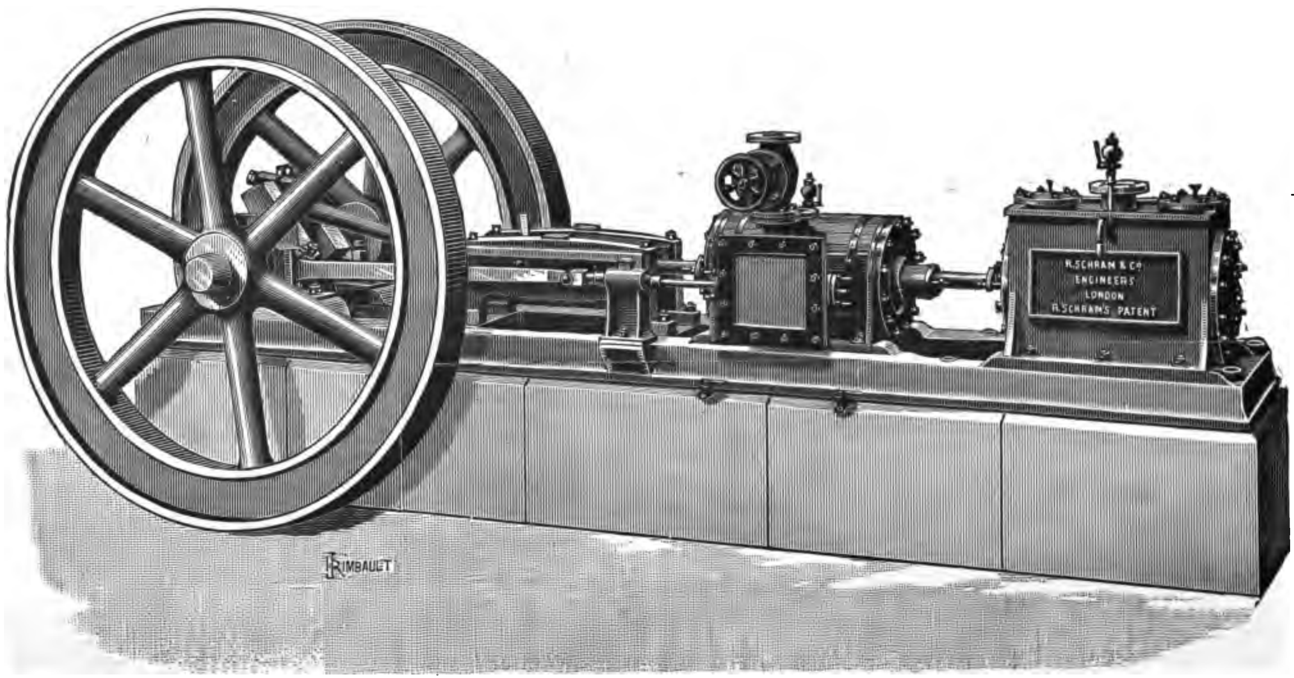


Fig. 17. The Ingersoll-Sergeant Steam-Driven Air Compressor.

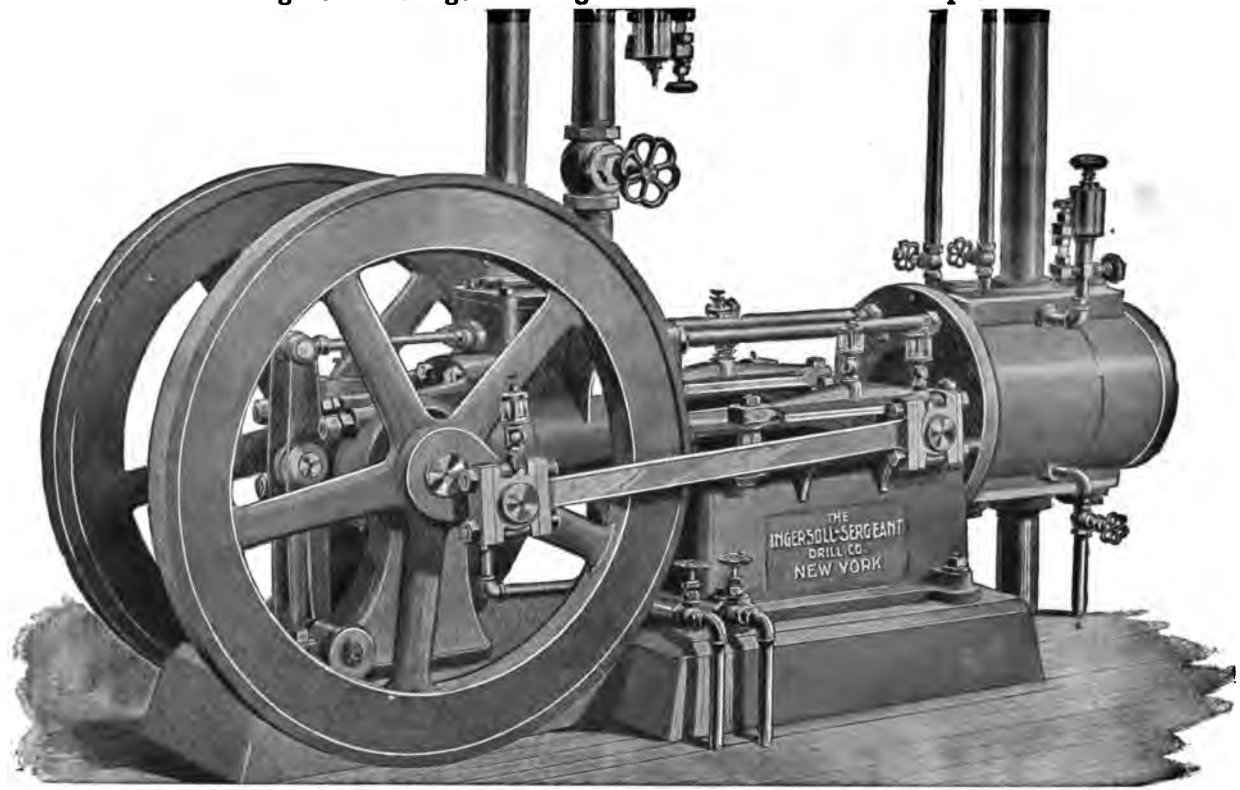
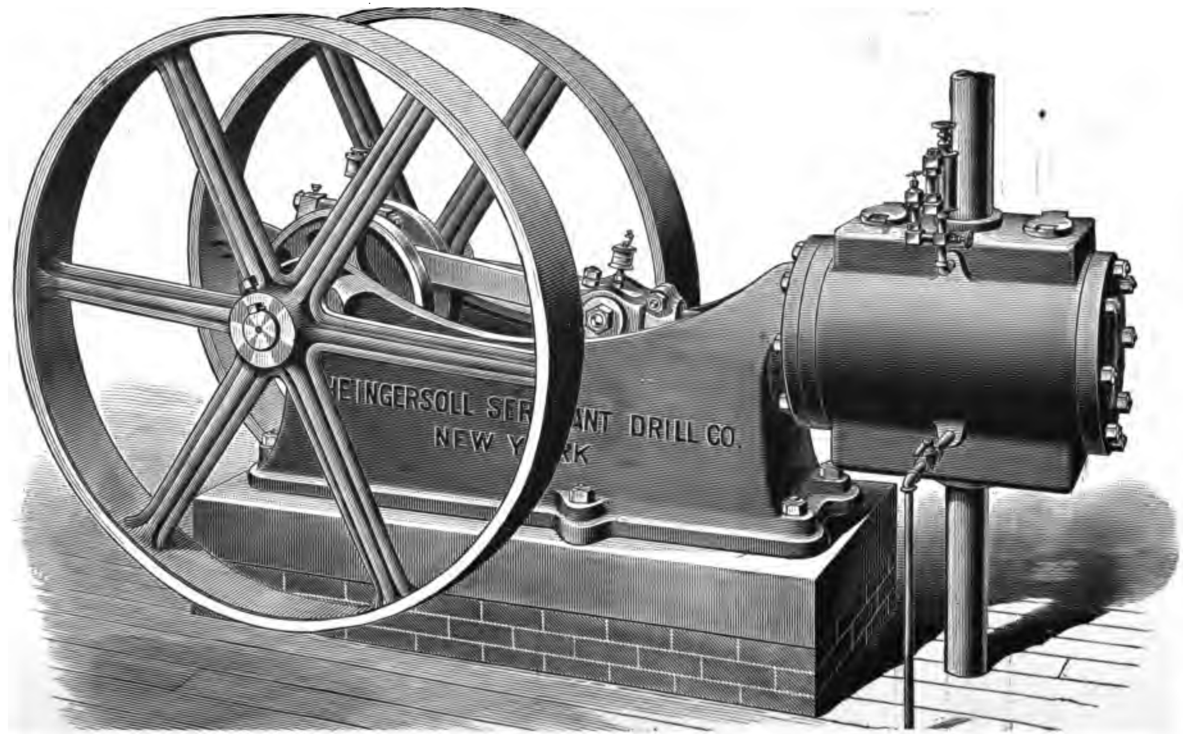


Fig. 18. The Ingersoll-Sergeant Belt-Driven Air Compressor.



With increased knowledge as to the laws governing its transmission and use, with greatly increased efficiency in the methods of obtaining the air under pressure, and with the use of engines requiring but one-fifth of the original amount of coal required to drive the compressors, compressed air is rapidly taking a leading part in power transmission. For mining and underground work it has advantages which cannot fail to insure its increasing and continued use as its merits become better understood.

Compressed air is simply air under pressure, usually for 60 to 80 pounds to the square inch for quarry work. It is well known that the air leaves the compressing cylinder hot (from 200° to 400°, depending on the initial temperature of the air and its final pressure). This heat represents power expended, or energy.

Where this heat has been allowed to be lost by radiation, resulting in a shrinkage in the volume of the air as delivered from the compressor, the shrinkage amounts to a loss from 20 to 30% in efficiency. This can, however, be provided for, as explained further on.

The only other objection of any weight has been the tendency of the air to freeze. This freezing occurs usually in the exhaust or where the air is expanded. An effect of this expansion is a pronounced drop in temperature, which fully accounts for freezing; but the difficulty can now be overcome. In the difference between the temperature of the air at the compressor and the final temperature of the exhausted air, the loss mentioned above has occurred. It is evident, therefore, that if this air were as hot just before being used as when it left the compressor cylinder, the temperature of the exhaust would be about the same as when the air entered the cylinder for compression, and this would give an efficiency in transmission of 100%, less only the friction and leakage in the pipe, which need not exceed 1½ to 2%. This added to say 10% lost by the compressor gives a total loss of only 12%, and the remarkably high net efficiency of 88%, against the usual efficiency of about 40%, as realized from steam power in general stone quarry work.

To make more clear the influence of heat on the economical use of compressed air, assume a compressor of straight line pattern, and of such size that 100 horse power is developed in its steam cylinder, as shown by the indicator. Allowing a loss of 10% or 10 horse power for friction, condensation &c., 90 horse power are delivered by the air cylinder in hot air. If this air is used in driving a second engine placed so close that the air loses none of its heat by radiation, it will develop 90 horse

power, less the friction and leakage, If, however, this second engine is placed at such a distance from the compressor that the air is cooled to the same temperature as that at which it entered the compressor cylinder, that is, the temperature of the outside air, the shrinkage in volume of air will be such that the second engine will develop only about 60 horse power.

Reheating the air can, however, be resorted to at slight expense, resulting in a higher efficiency by the use of compressed air than can, perhaps, be realized by any other means. If the heat lost is restored just before being used in the second engine, drill or pump, and the air re-expanded thereby, *there will be no loss of power or efficiency,* excepting only the amount of friction in the compressor, and friction and leakage in the pipe, which need not exceed $1\frac{1}{2}$ to 2%, and the freezing will be entirely overcome.

With the Sergeant air reheater, illustrated on page 206, a perfected system of reheating has been obtained which is simple and inexpensive—but little fuel is required (scarcely more, in fact, than is used by an ordinary stove)—and by its use compressed air becomes the ideal means of transmission of power for many purposes.

While it is entirely practicable to thus reach the highest point of efficiency, and this at moderate expense for plant, compressed air would still be more economical than steam for most large quarries, even without reheating, and leaving out altogether the 30% possible gain. The condensation of steam is so enormous under the system of piping found in most quarries that the balance in economy would be found in favour of air power.

Compressed air can be carried for miles with but little loss of either efficiency or pressure, provided the pipe is large enough, while the limit with steam in uncovered pipes is reached in a few hundred feet. With the steam pipe, uncovered and laid on cold rock, exposed to the wind, rain and snow, and frequently with water from the damp walls dripping on it and running over it, the condensation is extremely rapid. This means loss of pressure, and more drills or more expensive pumps to do the same work, &c., &c.

At the Marble Cliff Quarries, Ohio, the pipe line is over 6,300ft. long, yet air at 80 to 90lbs. is delivered at the receiver. As the pipe is tight, the gauge shows full pressure at the extreme end of the line. The reason for this is apparent, as there is no condensation possible with compressed air.

At the Jeddo Tunnel, near Hazelton, Pa., where compressed air at 60lbs. pressure was carried 10,860ft,, the gauges were tried on both ends of the line, but no difference in pressure was found. As they were convinced that "something was wrong," the gauges were sent to the shop for repairs. The result was the same after the gauges were returned "repaired and adjusted," and it is evident that this apparently perfect economy in transmission was due to the fact that a tight pipe, rather large for the work (5¼in.), was used, and the air moving slowly, the friction loss was too small to be recorded on the gauges.

The disadvantages of steam are great, as a good deal of water—condensed steam—collects in the pipes, even in the short time consumed in changing bits or in moving from one hole to another. This must be drawn out through the exhaust before the drill can begin to do good work. If this water from the different drills and pumps could be collected, it would be found to amount to a great many barrels in the course of a day. Each cubic foot of water from condensation represents one horse power wasted. There is another and serious loss with steam ; that of loss of capacity of the drills. With full pressure of dry elastic compressed air at the drills more work will be done than by the wet stream ; a less number of drills, drill-runners and helpers will be required for the same work, and these various reductions in the pay roll and coal bill may amount to the cost of the plant before it is worn out. It is a common expression, "two drills will do more work with air than three with steam."

For shaft sinking, as in mining, compressed air has particular advantages over steam. The majority of shafts sunk in the warm season require artificial ventilation. When power-drills driven with air are used, the exhaust furnishes a constant supply of cool, fresh air directly at the working faces. After a blast has been made, in either shaft or room work, the hose can be turned loose, and the whole volume of air furnished by the compressor used for driving out all smoke and gas, allowing work to be resumed in a few minutes, instead of waiting hours.

The use of steam in confined places for drilling, pumping, &c., is open to the objection that the heat thrown off in warm weather becomes so oppressive that it is difficult for men to do rapid work, and the constant hot drizzle from the exhausts of the pumps and drills increases the discomfort.

When steam is used to drive drills and pumps in shaft work, it is

necessary to carry a large exhaust column, or pipe, down with the work, to which the exhaust from all the machines used must be connected.

A cheaper grade of hose can be used with air, and will outwear several lengths of steam hose. As a matter of fact, the saving in hose alone equals the expense of keeping up the plant.

Less oil is required with air than steam. A little oil will last for hours in an air cylinder, and will ease the working of the machine. Steam burns the oil out in a few minutes.

It is evident that greater economy will be realized by the use of one central plant placed where fuel and water are most accessible, removed from all danger from blasts, falling derricks, &c., not subject to constant removal, furnished with an economical boiler plant, a compressing engine of high efficiency, fitted with an entirely automatic system of governing devices, using steam expansively, and requiring steam only in exact proportion to the amount of air being used in the works. This disposes of all annoyance and expense incidental to supplying coal and water to a number of different boilers, and there is only one fireman, and one boiler plant to keep in repair. All annoyance and expense from frozen pipes in cold weather, smoke, exhaust steam, and ashes are avoided

The compressing plant can be Straight Line, Duplex, or Duplex Compound Condensing, fitted with Adjustable Cut-off, with which the point of cut-off can be adjusted from $\frac{1}{8}$ to $\frac{7}{8}$ of the stroke, or with the well-known Corliss valve gear, giving the high efficiency of less than two lbs. of coal per horse power per hour, as compared with six to twelve lbs. generally necessary to do the same work when steam is used in the drills direct.

When the plant is non-condensing, the exhaust steam can be made available for heating the feed water, by which utilization of the otherwise wasted heat the economy is increased from 10 to 15 per cent. This, of course, is impossible where the heat of the exhaust steam from drills, pumps, hoists, &c., is a total loss. Any regular pattern of steam-actuated compressors can be supplied with condensing apparatus where the water supply will admit of its use, giving an increase in steam economy of about 20 to 35 per cent. over the same type when run non-condensing.

In order to get a steady working pressure and uniform velocity it is necessary to have an air receiver, which is generally placed in close proximity to the air compressor. The air from the compressor is

delivered into the receiver, and discharged at one end into the main air pipes, which convey the air into the mine, and to the different places where it is required.

Chain Heading Machine for Thin Seams.

AIR POWER.

DEPTH OF HOLING, 5, 6, OR 7 FEET. WIDTH, 39 OR 44 INCHES.
KERF, 4 INCHES. EFFICIENT AIR PRESSURE, 60 lbs.

The heading machine, as will be seen from the illustration, Fig. 19, is a breast machine, making its cut straight to the front.

The principal parts are three in number :—

1.—The bed frame, which is the stationary part, being jacked both front and rear to the face and roof.

2.—The sliding chain cutter frame, which, as its name implies, slides on the bed frame and carries the revolving chain in which are fixed the knives.

3.—The motor carriage, to which is fixed the cylinders and gearing, and which is attached to the sliding frame by steel castings.

All the bearings are of bronze. The chain carrying the cutters is made of cast steel solid links, coupled together with drop forged straps, having lugs at each end, which provide bearings for the cutter links.

This construction enables the chain to be taken apart and be replaced in a very short time. The bits are straight, with a slight hook at the cutting end, and are so shaped that they can be re-sharpened many times, allowing about 75 per cent. of the steel in each bit to be used.

The cutter-head is bolted together, and can be readily taken apart; at the corners of the cutter-head is an idler, on which the cutting chain runs, and in order to provide for an ample supply of oil to these, a double bearing is used which allows space for packing, thus providing a constant lubrication.

The machines are built to undercut 5 feet, 6 feet and 7 feet, the width of each cut being either 39 inches or 44 inches, with a kerf of 4 inches. All parts are built to template, and in case of accident can be replaced with little delay.

The *modus operandi* is as follows :—The machine, mounted on its truck, is hauled to the face of the seam, the truck running on the rails or temporary track used for the mine tubs, the rear end of the truck is

Fig. 19. Chain Heading Machine for Thin Seams.

lifted, and the machine slides off, reaching at once its proper position to commence cutting. Connection having been made with the hose, and the frame firmly jacked, the machine is ready to start. The operator generally remains at the rear of the machine, his work being practically at an end until the machine has finished its cut. He then reverses the gearing by means of a lever, and the cutter frame travels back until it reaches a point where it is automatically thrown out of gear. The machine is then ready to be moved for its next cut, which can be readily done by two men, by means of crowbars, the front end sliding on its own shoe boards, the rear end on the skid boards provided for the purpose. In addition to the operator, one other man only is required, to set the front jack, help shift the machine, and shovel out the slack. After the length of a face has been holed, the machine is again placed on its truck (this is easily accomplished by the two men in charge by means of the winch on the truck). A horse then takes it to the next stall or face to be holed.

The average time occupied from the commencement of one cut to the beginning of the next is from five to eight minutes, varying with the hardness of the rock, the depth of cut being up to 7 feet by 39 inches or 44 inches wide, about 4 inches in height being removed. The machine will cut equally well in different kinds of materials.

The average horse-power absorbed, as taken from a large number of readings in seams of varying hardness, works out at about 12. These machines are extensively employed for pillar and stall and heading work, and in many pits are doing good service in longwall work where the floor and roof are good.

Air Power Drilling Machine.

WEIGHT, 170 LBS. EFFICIENT AIR PRESSURE, 60 LBS.

The Jeffrey air power and electric drills form a very simple piece of machinery with few parts, and, moreover, can be operated and moved from stall to stall by one man. The machine will drill a hole 6 feet deep in coal in less than a minute ; this and the ease with which it can be moved recommends its use in mines where drilling has to be done.

Sergeant Air Reheater.

The air enters the annular chamber at the top of the heater, and passes in a thin sheet over the heated surface of the entire heater into the annular chamber at the bottom, which forms the outlet. The heater being in the form of a truncated cone, makes a perfect combustion

Fig. 20.

chamber for the fuel, and also increases the air passage, allowing the air to expand in its downward course while it is being heated, without increasing its velocity.

The heater is fed with fuel through the door on top, the same as any regular self-feeding stove, and requires no more care. It can be made to buru either gas, oil, coal, or coke, and when made for coal or coke, it is furnished with a shaking and dumping grate, ash pit and damper for smoke pipe. The outside of heater is jacketed with sheet iron, and filled in with non-conducting material.

From tests made with this heater it has been found capable of heating 340 cubic feet of free air per minute at 40lbs. pressure to 360° F., giving a gain of 35% in the measured amount of work done by the air after passing through the heater, compared with the same volume of air when used cold.

A heater of this size can heat less air to a higher temperature, or more air to a lower temperature, than stated above; but, if it should be required to heat more than 400 cubic feet of free air per minute, to get the best economy it is advisable to use the heaters in series, allowing about 400 cubic feet of free air per minute for each heater. The heater should be placed as near as possible to the point where the air is to be used, and the outlet pipe should be as short as possible, and well covered, so that the air will retain its heat.

ROCK DRILLS

ROCK DRILLS.

The power of a Rock Drill is in direct proportion to its diameter of piston. *It is of the greatest importance that a Drill of Proper size be used for the work intended.* It is impossible to determine by figures that a Rock Drill of a certain diameter of piston will be best suited for a particular piece of work. This can only be learned by experience.

Fig. 21. The "Schram" Improved Rock Drill.
For working with compressed air or steam direct.

It is a common thing to see Rock Drills of too small a size used in work where a larger drill would save money, and it is like putting a boy to do a man's work. It costs as much to feed a boy, but the man accomplishes more in the same time.

There is a distinct tendency of late years toward the use of heavier and more powerful machines than were used for the same work only a few years ago. A drill too small for the work intended is never a paying investment, and the slight discrepancy in price between a small drill and one of proper size should never be allowed to influence the matter, as this small difference will, in many cases, be made up every week in the difference in work done. Again, experience shows that the larger machines are much more durable and economical in repairs, not apt to break down, and will outlast several of the smaller ones under the same conditions.

Fig. 22. The "Optimus" Compound Rock Drill.
(P. J. Ogle's Patent.).
By Messrs. Richard Schram & Co., London.

On the other hand, large drills should not be used for shallow holes of small diameter in soft rocks, when the time taken to move the machines is out of proportion to the time it takes to drill the hole. Many are using rock drills, as they think satisfactorily, when a larger or a smaller, or a different pattern of machine would be a surprise as to its greater capacity. Good machines are sometimes condemned when the only trouble is in their being unsuited for that particular work.

A matter which frequently receives too little attention from the drill runner is the keeping of the bits in the proper shape. Generally speaking, they should be as thin and sharp as they can be made without breaking or sticking. It is a common thing to run × or + bits till they are battered or worn so blunt as to make cutting out of the question ; it is then a matter of brute force. Two or more sets of steels should be used, so that a sharp set is always available without waiting for the blacksmith. Always remember to keep the bits dressed for as small a hole as will do the work ; there is just four times as much rock in 2-inch holes as there is in 1-inch ; an eight of an inch difference in the size makes quite a difference in the drilling time. The size of the

bit or its sharpness affects the speed every time a blow is struck. When a drill is striking 200,000 blows per day these little differences count up to a great deal every day, to say nothing of months or years. A main point is to keep the machine pounding every possible minute of the time ; lose as little time moving and changing as possible. The rule is to have the bits as thin as possible up to where they begin to make

Fig. 23. The Ingersoll-Sergeant Rock Drill.

cornered holes, in which case the remedy is to thicken the bit $\frac{1}{16}$-inch or more. If the + bit rifles the whole, try the × shape. If the drill sticks, it is a thousand to one that the trouble is with the bit, or in the hole, and not in the machine. See that the corners are dressed well

back where the side of the bit touches the wall of the hole, so that the rubbing surface is small. A dulled bit often takes quite twice as long to get down as a sharp one, and a good driller can accomplish twice as much as a poor one by making his moves and changes quick, keeping his bits sharp, and giving the machine its fullest stroke without striking the head:

Keep the hole clean, the pressure high and dry, and the machine well oiled, so that the piston is almost "nipping" the head every blow, unless in seamy or treacherous rock.

The "Optimus" possesses some very distinct and important features not to be met with in any other drill yet introduced. It works on the compound principle, and an enormous saving of air is the result. The lower end of the cylinder is bored out to a larger diameter than the upper end, and, during the forward stroke of the piston, the air is exhausted from the cylinder and the air at full pressure is simultaneously admitted to the upper end of the lower end of the cylinder, thus giving a most powerful and rapid stroke. The air that has been used to make the forward stroke, instead of being exhausted to the atmosphere (as in ordinary drills), is taken through the valve to the underside of the lower piston and utilised for the backward stroke; the result of this, in combination with other improvements in the construction of this drill, is that the consumption of compressed air is 40 per cent. less than that of any other drill of the same size and stroke; and in addition to this enormous economy, the following further advantages are obtained by the adoption of the "Optimus" drill:—

Considerably smaller air compressors and boilers are required, and consequently reduced first cost of plant.

Great reduction in quantity of coal burnt, and feed water required for boiler.

The cost of transport of the plant (being smaller) will be materially lessened.

The Diamond-pointed Core Drills.

The Diamond Drill is not a competitor of the Percussive Drill. The function of the one is to ascertain the nature of the material, and of the other to assist in excavating it. Experience has taught that, wherever the steel bit can be used, it does cheaper work than the diamond bit; but the steel bit is limited in its application, and cannot be used in boring holes for the purpose of removing a core, thus producing a sample of the material perforated. This work belongs to

the Diamond Drill; hence it may be called the "path-finder" for the Percussive Drill, and for this purpose it is invaluable.

The Hand-Power Diamond Drill, illustrated, is a light, compact, portable, and durable machine, eminently suitable for prospectors, as it takes out a solid cylindrical core, and it can be economically and successfully operated by hand or horse power in localities which are inaccessible to other styles of drills.

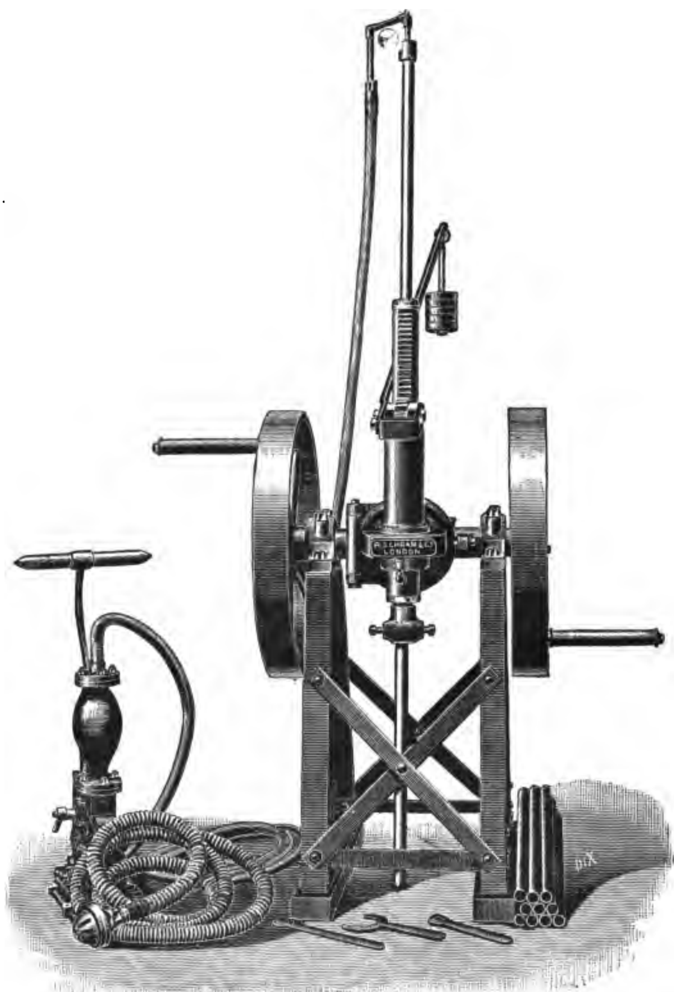


Fig 24. Diamond Boring Machine for Hand Power.
By Messrs. Richard Schram & Co., London.

As shown in Fig. 24 on the previous page, it is set up for drilling from the surface, but in addition to its uses as a prospecting machine, it is also adapted for underground prospecting in mines. For this purpose it should be used on the two columns only, the back leg and the wooden frame being removed.

The drill is adapted for applying horse, electric or steam power by removing the handles and placing a driving pulley on one of the shafts. The size of this pulley is determined by the driving pulley on the motor, the pulley on the drill running from 250 to 350 revolutions per minute.

The Hand-Power Diamond Drill is generally fitted to bore $1\frac{3}{4}$in. holes, taking out a core of $1\frac{3}{16}$in. diameter, its capacing being 350ft. of said diameter hole; but the size can be varied from $1\frac{1}{2}$in. to $2\frac{3}{8}$in. diameter, as desired, the depth being more or less according to the diameter.

The speed of drilling depends upon the power applied and the hardness of the rock. When operated by hand power, which is the slowest, in very hard rock, 6 to 8ft. per day; in medium, 10 to 15ft. per day, and in soft rock, 15 to 25ft. per day have readily been attained.

The total weight of this machine, exclusive of the columns is only 120lbs., which can be readily divided into small and convenient packages not over 20lbs. each, thus forming a drill which can be easily transported by men, and successfnlly operated by them in remote localities, where speed of operation, durability, and accuracy are desired.

The No. 4 Diamond Drill is mounted for surface exploring on a bed-plate, with a compound geared hoisting drum attached, provided with a brake band, to be used in handling the rods, and especially adapting it to the systematic prospecting of mineral properties, locating hard ore veins or pockets, and showing not only their distance from the surface, but also dip and exact character.

The drum and gearing are so proportioned that 800 feet of rods can be hoisted safely and rapidly.

With this machine, and the use of a 4 h.-p. horizontal locomotive-style boiler, mounted on broad-tyre wheels, an outfit is made which can be transported easily and with little expense.

Weight of the apparatus 385 lbs., which can be readily separated into 75 lb. packages for transportation. It occupies, off the columns, a space only 20 inches square, particularly adapting it for service in confined places. It is calculated for boring $1\frac{3}{8}$ inch hole, taking out

$\frac{15}{16}$ inch core to a depth of 800 feet, or (special outfit) $1\frac{3}{4}$ inch hole, $1\frac{3}{16}$ inch core to a depth of 500 feet.

Diamond Boring Machine,

for driving by belt from portable steam or oil engine or electric motor, suitable for depths of 750 to 1,000 feet.

This is a powerful and strongly-built appliance, mounted on wrought iron frame, giving it extreme rigidity with comparative lightness. It is specially adapted for boring deeper holes, and where larger cores are required. The machine is fitted with fast and loose pulleys, arranged for driving by belt from a steam or petroleum engine: belt shifting attachment; hand regulating screw; and wrought iron lever and weight, for counterbalancing the weight of the rods when this becomes necessary. It is also provided with two rope pulleys, which can be put into gear when it is required to raise the rods.

From these pulleys the rope is carried to a block fixed at the top of shear legs or a suitable derrick immediately over the bore-hole; but when deep holes are being put down it is better to employ a separate winch.

Before raising the rods, the centre of the machine is swung back, giving free access to the bore-hole, and the free end of the rope attached to the boring rods. The engine is then started, the height of the lift being controlled by the belt-shifting arrangement.

The Ingersoll-Sergeant "Baby" Drill.

Its best work is done where the holes are from $\frac{5}{8}$ to $1\frac{1}{8}$ inches in diameter up to three or four feet deep. It is frequently used for larger holes, but for heavier average work, or in broken ground, it is advisable to use a more powerful machine.

In granite it has frequently done as much work as ten men, drilling $\frac{3}{4}$ inch holes 4 inches deep in $\frac{1}{2}$ to $\frac{3}{4}$ of a minute. Its record, with a man and a boy handling it in limestone, is 125 horizontal holes in 100 minutes, and 150 vertical holes in 75 minutes, the holes being 1 inch diameter and 7 inches deep. It acts most effectively with compressed air or with steam at high pressure, and as close to the boiler as is necessary to insure dry steam.

Fig. 25. The Ingersoll-Sergeant "Baby" Drill.

Auger Drills.

The drill consists of a small reciprocating engine, actuated by compressed air, and driving a feed-bar by means of gearing. The screw feed-bar has an automatic variable feed of from six to 1,000 revolutions per inch of hole, thus adapting itself where hard substances are apt to be found. The whole machine is simple, strong and durable, requiring but little air to operate it, and is easily moved from one part of the mine to another. The column is adjustable, and is made in different lengths for the different thicknesses of veins.

It drills coal at the rate of about 6 feet per minute, and slate and fire clay about 3 feet per minute. Holes have been drilled up to 30 feet in depth.

Another sized drill, mounted on tripod instead of column, is a light, portable machine, designed for veins too thick for the use of a column. It is fitted in two minutes, and drills some materials at the rate of 8 feet per minute. Holes can be made at any angle ; it is adjustable for height, and will drill within 4 inches of the top, sides, or bottom. A variable feed is also supplied. Total weight about 125 pounds.

The air-feed coal drill adaptable to potash working consists of a small rotary engine, hung in an upright frame, with points top and bottom to engage by adjusting screws with the roof and floor of the mine. A dog or brace is used to hold the frame rigid as the auger bit advances. Power is transmitted to the feed-bar from the engine by gearing.

PUMPING ENGINES.

PUMPING ENGINES.

Principles in the Selection.

Where *steam power* is used for draining mines it is in most cases desirable, both for convenience and safety, to place the boilers on the surface.

It therefore becomes necessary to transmit the power generated above ground to that point in the mine where the water collects, and where, therefore, the pumps have to be placed.

There are three principal methods by which this transmission may be effected :—

1. The direct connection of an engine placed upon the surface with the pumps in the mine by means of pump rods.
2. The conveyance of the steam itself to an engine placed underground.
3. The use of some intermediary agent which shall absorb the power generated by an engine placed upon the surface and give it out again at the pumps.

Of these three methods, either the first or second is most usually employed where the power to be transmitted is at all considerable, and the pumps tolerably accessible. But the third system is extremely useful where comparatively small quantities of water are to be pumped or where it collects at points distant from the shaft foot.

Of the two first systems, Method No. 1, *i.e.*, the surface engine, has the two following important advantages over Method No. 2, the underground engine. The surface engine is much the more economical in steam, and therefore in coal, in boilers, both capital cost and up-keep, and in stoker's wages.

The surface engine is safer in cases where the mine is liable to flood.

Owing to the weight of the spear rods and pump work, which, when set in motion, form a reservoir of energy, steam can readily be used expansively in an engine of the surface type. But when steam is carried down the shaft, and a duplex or other direct-acting pump is employed, the only reservoir of momentum is that provided by the motion of the pistons, rams and water-column. The resistance of the pump plunger is in consequence practically constant, and boiler pressure must be admitted throughout the greater portion of the stroke. The

economy of expansive work is therefore sacrificed. To mitigate this loss, compound engines, which use the same steam twice over, are often adopted with great advantage as compared with the single cylinder or ordinary duplex steam pumps. But even when this is done, the number

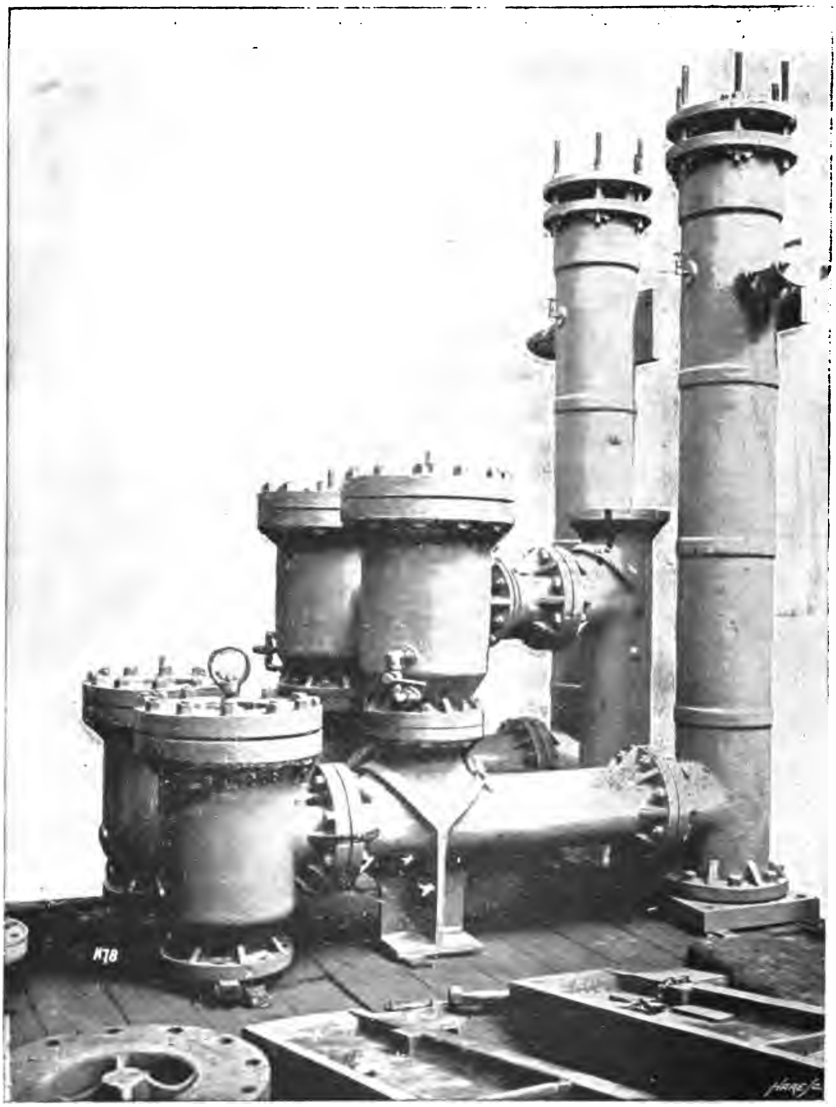


Fig. 26. Surface Vertical Single-Acting Plunger Pumps.
For the New Russia Company,

of expansions which can be obtained is very limited, and there is also loss due to the fall of pressure between the cylinders, so that the economy of a true expansive-working engine cannot be attained.

Another point which tells in favour of the superior economy of the surface engine is the reduction of the loss which arises in a subterranean one by condensation in the steam pipes and the consequent use of wet steam. For, if an engine be placed above ground, the boilers can usually be arranged close to it, whereas, in the case of the lower situation, a long range of pipes, and these often fixed in a wet shaft, is, in most instances, necessary.

An engine at the surface is more under the observation of the mine manager than if its position be below. Moreover, the engine-house also can be more conveniently lighted and ventilated, and more ample room left for access to all parts of the machinery than is possible when it is underground. There is, therefore, a much greater tendency to keep the former in that thorough repair upon which economy so much depends.

In deep shafts exceeding, say, 1,300 to 1,400 feet there is a further loss of economy in the underground type, as owing to the quantity of steam used compared with that of the water pumped it becomes necessary to work non-condensing, otherwise the mine water becomes overheated. This also entails the inconvenience of providing for the disposal of the exhaust steam.

For these reasons the steam consumption of a surface engine is not much more than half that of even a good underground engine of equal power, and not more than one-third of that of the numerous small duplex or single cylinder steam pumps frequently used.

As an approximate estimate, the duty in lbs. of water raised one foot high per cwt. of ordinary engine coal burnt may for single or duplex steam pumps be taken as from 12 to 25 millions, according to the size of pump, steam pressure, and conditions of work; and for a compound steam pump from 30 to 40 millions; while a surface engine will, in ordinary work, give a duty of from 50 to 60 millions.

Not only is the surface type superior in economy, but also, in the case of mines liable to flood, it has another great advantage over an underground pumping engine, for the pumps can be kept at work even when the mine is under water, and if, as should always be the case in such mines, the bottom set is fitted with buckets, these and the clacks can be withdrawn and changed from above the water level,

Objection is sometimes taken to the surface mining engine on the ground of the supposed risk of breakdown through the failure of the spear rods or pump work. Such breakdowns do of course take place, but with properly designed machinery the risk is not serious. In designing engines for this purpose two points have specially to be kept in view :—

1. That the reversal shall be as gradual as possible, so as to minimise the strains on the spear rods and pump work.

2. That if unfortunately a breakage should take place, the valve gear shall be of such a nature as to control the engine and prevent it from doing serious damage.

In the first place, the engines are direct-acting, *i.e.*, without fly-wheels, so that at each stroke the spear rods are started gradually from a state of rest, and the jerk which is liable to occur when the momentum of a fly-wheel is opposed to the inertia of heavy spear rods is avoided.

Secondly, Davey's valve gear, as used in surface mining engines, provides in case of loss of load for the immediate cutting off of steam, cushioning of exhaust, and, even in extreme cases, for putting live steam against the engine.

The surface pumping engine, as fitted with the differential gear, is therefore safe, economical and accessible.

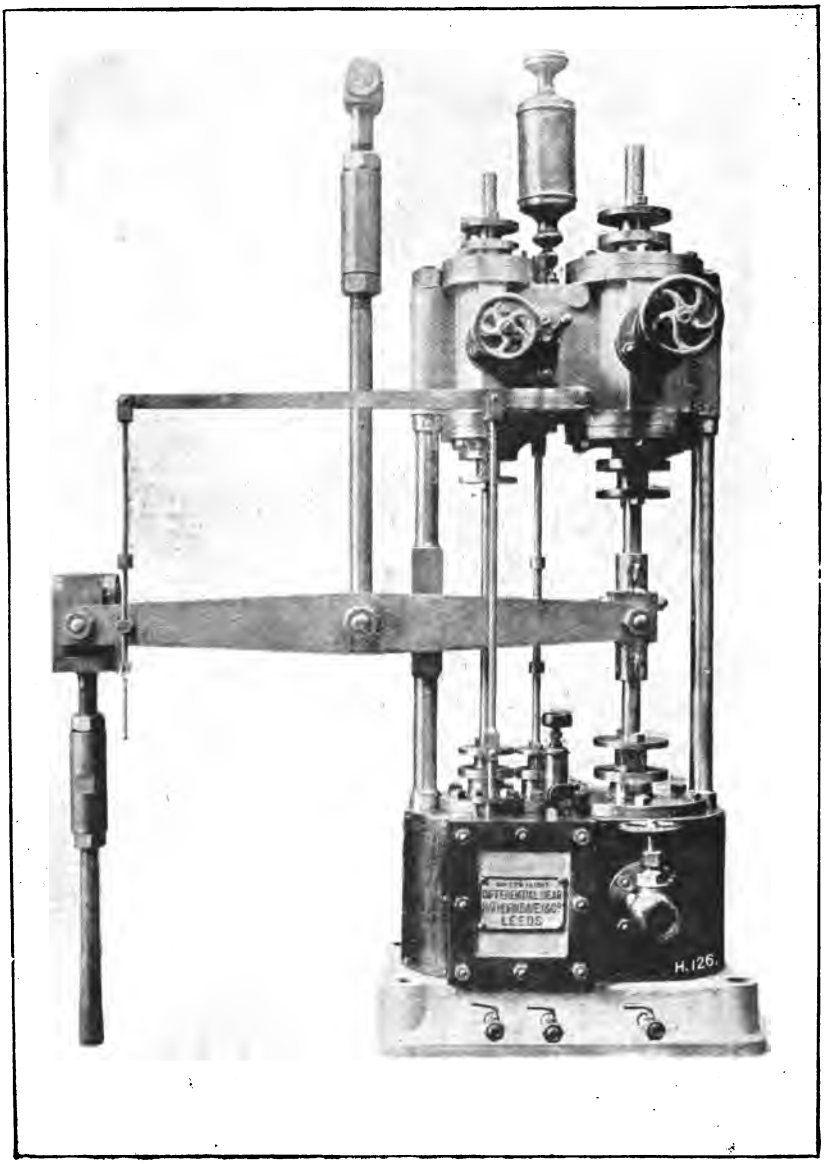
With reference to the above comparison, the following observations made by Mr. James Davison, of the Yarlside Mines, in a paper read before the Institute of Mining Engineers at Furness Abbey, July, 1899, are, in view of his extensive experience in mine pumping, of especial interest.

"1. Engines with geared wheels, pumping shafts, cranks, &c., where heavy pumping is concerned, have been found very unsatisfactory and expensive in working and repairs; the various and severe strains set up in the several working parts are almost sure to lead to occasional, if not frequent breakdowns, and the transmission of power from part to part must occasion loss. The experience gained at these mines is in condemnation of the use of the geared engine for heavy pumping.

"2. The Cornish engine is well adapted to its work, but being only single-acting, it cannot do as much work as a similar sized double-acting engine will do. Its action during the stroke is more irregular and violent than the Hathorn-Davey engine, causing greater shock in the pump, and making it necessary to divide the pump into shorter lifts. The ponderous beam and strong building necessary to carry it occasion

Fig. 27. Davey's Differential Valve Gear.

For regulating the admission and release of steam used in Direet-Acting Pumping Engine.



greater outlay in erecting this class of plant, and in case of loss of load in the pit, the result is often a very serious breakdown. With these exceptions, and as regards repairs in an ordinary way, and the matter of duty, the engine does not appear to be inferior to any other type of engine.

"3. The Hathorn-Davey engine is double-acting, and, therefore, a much smaller engine will do the same amount of work as that done by the larger sized single-acting Cornish engine. In addition to this, it allows of two rams being used, which discharge into the same delivery pipe; there is also less shock in the pumps, owing to the more uniform speed during the stroke, consequently longer lifts can be used, which means fewer clack boxes, rams, stuffing boxes and glands, which lessens the first outlay and also the cost in working, and a much cheaper building can also be used to house the engine. There is further the fact that loss of load in the pump does no damage to the engine, and this has been proved at the No. 10 Pit Hathorn-Davey engine on several occasions. This engine has been at work nearly nineteen years, and has never been known to strike the cylinder end.

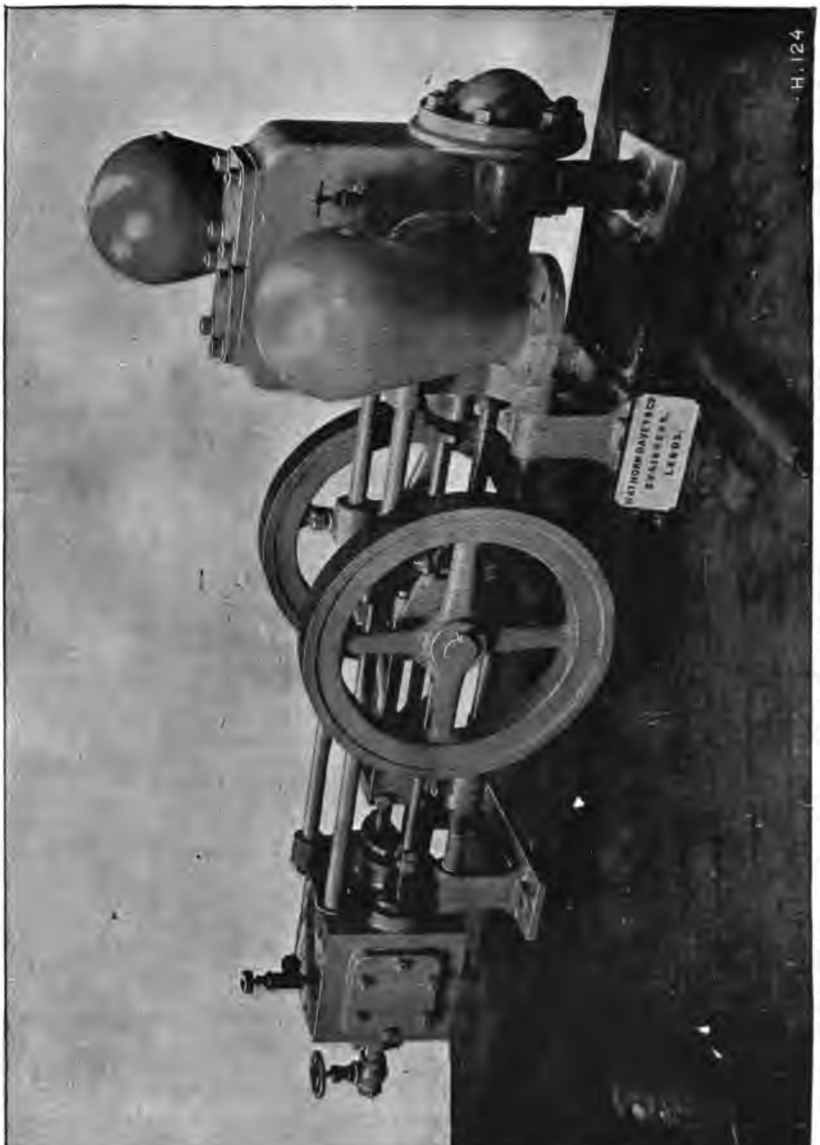
"For the Cornish engines the lengths of lift vary from 240 to 360 feet, but it is found that the shorter lifts are much better in working, and are not so troublesome as regards keeping the joints tight and maintaining the glands in good order.

"With the Hathorn-Davey engine there is no trouble with blown-out joints in the pumps, although the lifts are over 378 feet in vertical height; they work without shock, and the glands will last for two years without repacking."

On the other hand, direct-acting underground pumping engines are much less in capital cost than the surface engine, probably about one-half the amount for the same horse-power, and they do not take up space in the shaft with spear-rods and guides, as is necessarily the case with engines of the surface type. They are, therefore, very largely adopted where fuel is cheap and capital cost an important consideration.

Direct-coupled rotative pumping engines are sometimes employed underground with the view of obtaining more economical work than can be got from the direct-acting type. But these engines are more costly than the latter species, require more expensive engine rooms, and except for small sizes are less safe for underground work, while the objections of distance from boilers and difficulty of inspection of course apply to them equally with the direct-acting engines. The non-rotative type is, therefore, more generally employed.

Fig. 28. Direct-Action Rotative Steam Pump.



These are suitable for use in cases in which the water to be pumped is within convenient suction distance of the engine-house floor, and where the scale of work is too small to warrant the cost of compounding.

The third method of transmission, *i.e.*, the use of some intermediary agent to absorb the power generated by the engine and give it out again at the pumps, is not very largely used excepting for small installations or where the water to be pumped is specially inaccessible.

The chief intermediary agents employed for this purpose are :—

Compressed air ;
Electricity ;
Water under pressure.

Compressed air is here the least economical. For firstly a rise of temperature takes place during compression, the result being that the resistance to the compressor piston is considerably greater than the effective pressure which the air is capable of again giving out, after having been cooled on its way to the pumps.

And secondly, unless an expansive working motor is employed, which, as offering practical difficulties is not usually done, the driving cylinder is on release filled with air nearly at admission pressure, the energy contained in which is wasted. In such a case the resistance diagram, which would be described by an indicator attached to the cylinder in which the air is compressed, would consist of two parts first, the area contained between the atmospheric line and a compression curve described during the portion of the stroke travelled over by the compression piston before the air reaches the delivery pressure : and second, a comparatively short parallelogram (the relative length of which depends on the pressure required) described during delivery, while the diagram described by an indicator placed on the motor cylinder would be nearly equivalent to the parallelogram only, the expansion portion of the compressor diagram being lost.

There are also other losses, the principal of which is that arising from clearance in the compressor cylinder.

For these reasons the efficiency of a compressed air plant, *i.e.*, the work done in water pumped compared with the indicated horse-power of the driving engine, cannot be taken at more than about 30%.

On the other hand compressed air is safe, the pipes occupy little room, and the exhaust air can be allowed to escape directly into the mine, obviating the necessity of a return column and assisting ventilation : therefore, in spite of its low efficiency, compressed air pumping may in some cases be advantageously adopted where the amount of work demanded is not very considerable, and where air compressing plant is already installed for other purposes at the mine. *See page* 195.

Electricity is now frequently used as an intermediary for conveying the energy of a steam or hydraulic engine on the surface to pumps placed in the mine. It is, of course, most applicable where water power exists in the neighbourhood, as by the facility of transmission which it offers, power, which could not otherwise be utilised, becomes available. But even when a steam engine has to be employed to generate the required electricity, this system can be advantageously used where an electrical plant for other purposes is already installed on the mine, and the quantity of water to be pumped is not large enough to justify the putting down of separate plant expressly to deal with it, or when the water to be pumped is too distant or inaccessible to admit of the use of ordinary pumping plant.

When power has to be generated by a steam engine, electrical transmission has the advantage that the dynamo can be directly coupled to the driving engine, and the latter worked expansively and at a high rate of piston speed. On the other hand, the step between the speed of the electric motor and that of the pumps is necessarily considerable, and power is lost by the belting or gearing, or both, employed to make the required reduction. There are also losses in the conversion of mechanical energy into electrical in the dynamo, reconversion to mechanical energy in the motor, and fall of potential in the leads. The efficiency of electrical plant, *i.e.*, the work done in water pumped compared with the indicated horse-power of the driving engine, is stated at only 70 to 80 per cent. The capital cost of electrically-driven pumps and motors for driving them may be taken roughly at about double the cost of a steam pump of the same capacity.

Hydraulic Transmission.—When it is not desirable to take either pump-rods or steam down the mine, hydraulic transmission is perhaps the best system to adopt, whether from the point of view of economy, safety, or simplicity.

As there is practically no alteration in the volume of the driving fluid the losses encountered with compressed air do not occur. Further, the resistance to a pump being nearly constant, pumping is work to which hydraulic motors are especially suitable, since they can be always worked at full load ; while at the same time, by merely throttling the driving water at the admission stop valve, the quantity of water raised can be readily adjusted, without in the slightest interfering with the efficiency. If suitably made, the pumps are absolutely safe and automatic, while the working parts are readily understood by any ordinary fitter.

Where main shaft lifting is already provided,, hydraulic pumps can be used to great advantage in places where a comparatively small quantity of water has to be drawn from a dip working. The requisite driving water can be taken from the shaft rising main and no additional plant, excepting the hydraulic pump itself, with supply and return pipes, is required.

The efficiency of this means of transmission, *i.e.*, the work done in mine water pumped compared with the indicated horse-power of the driving engine, may be taken as from 50 to 60%, depending on the

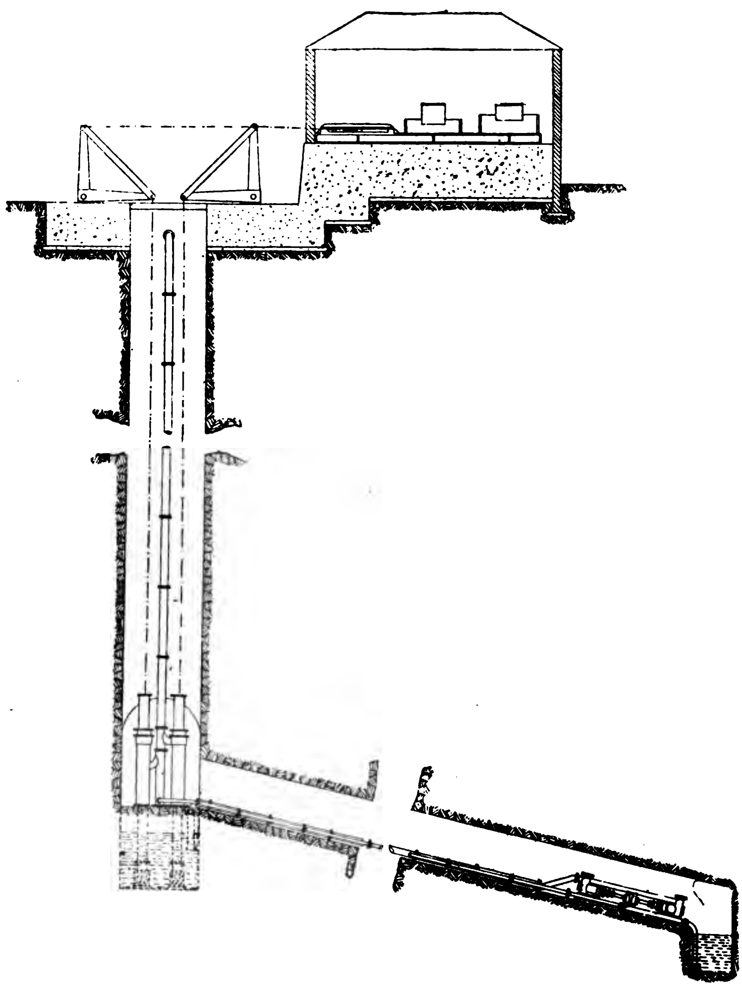


Fig. 29. Pumping Machinery driven by Hydraulic Power

size of the installation, height of lift, and length and size of the power and delivery pipes used.

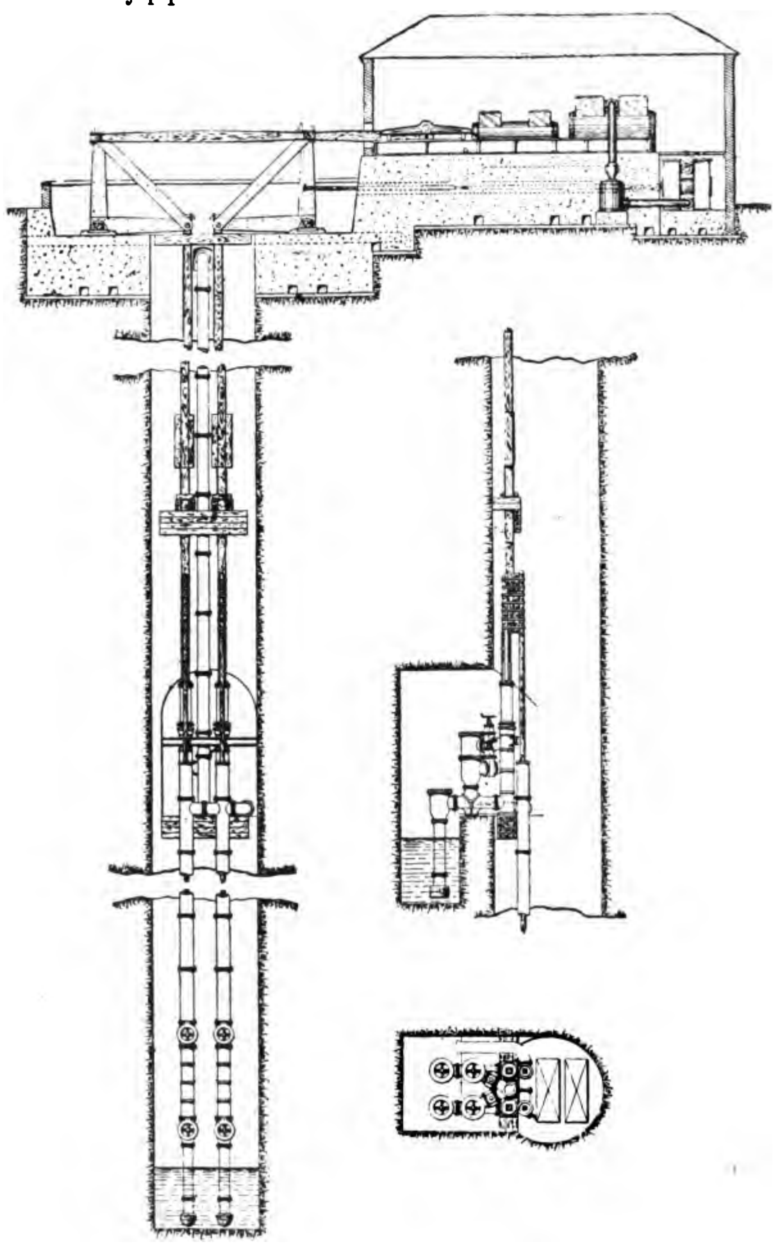
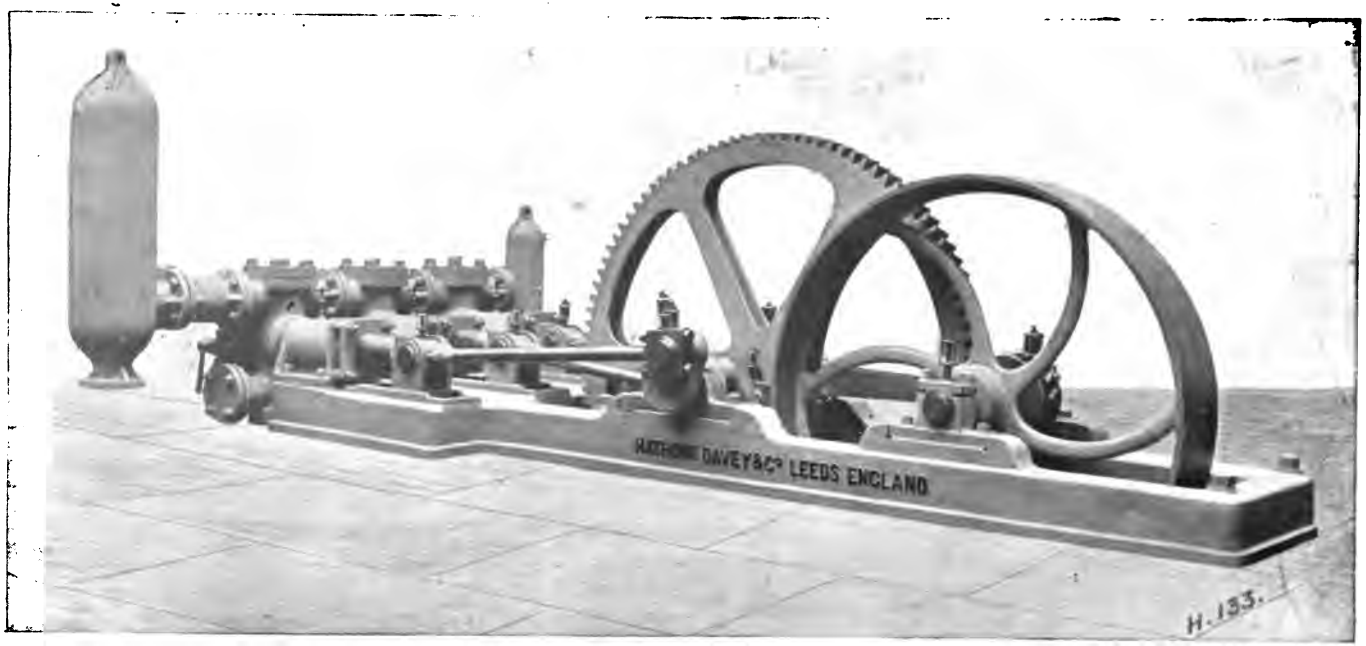


Fig. 30.

Fig. 31. **Horizontal Three-Throw Ram Pump for High Heads.**



Driven either by belting, ropes or electricity.
To raise 5,000 gallons of water per hour 600 feet high

Surface Differential Mine Pumping Engines.

Horizontal, triple, compound or single cylinder, differential pumping engines placed on the surface, actuating either bucket or plunger pumps, or both, in the shaft by means of spear-rods, are adopted in many mines, and are suitable for use in all cases where it is required to raise considerable quantities of water and where room can be found for the rods and guides in the pit shaft.

This class, in common with the Cornish variety, is much more economical in steam consumption than any other of the numerous kinds, for reasons we will recapitulate :—

1. The moving mass of the spear-rods enables the steam to be used expansively.

2. The boilers being placed close to the engine, the very considerable loss by condensation, which occurs when steam is taken down a mine shaft, is avoided.

3. The engine being on the surface is always under observation, and more easily kept in first-rate working order than is possible when placed underground.

A surface engine is decidedly safer than one underground where there is any liability to flood, inasmuch as the bottom set of pumps can be of the bucket type, so arranged that the bucket and clack can be drawn from above and replaced, even when the pumps themselves are under water.

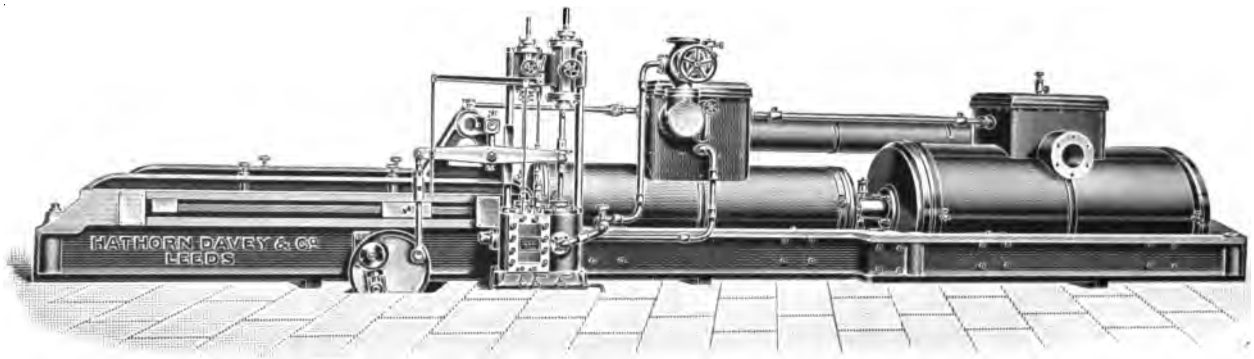
In the larger sizes they are provided with gear for regulating the length of pause between each stroke, thus enabling the engine to run at any required speed; and as an additional safeguard they are also furnished with a trip gear arranged in case of loss of load to release a catch and allow a weighted valve to fall, thus closing the pipe leading from the high to the low-pressure cylinder.

The pumps may be either of the bucket or plunger form as required, or both descriptions of fitting may be used, placed in series, one below the other.

They can either be arranged in pairs, in which case two quadrants and sets of rods are necessary, or singly, when one balanced quadrant and set of rods is employed.

When there is any liability of water rising above the point at which the pumps are to be placed, it is very desirable that the lower set should have buckets, so that the buckets and clacks may be withdrawn and changed, even when the barrels are submerged.

Fig. 32. Surface Compound Differential Pumping Engine.



For Sandwell Park Colliery
To raise 220 gallons of water per minute 645 feet high.

Pumping Water by Compressed Air.

THE POHLÉ SYSTEM.

This pump acts without pistons, without valves, without plungers, without rods, without cups, without buckets, and without any moving parts.

The simplicity of construction and the economy of operation and maintenance are the main important features characterizing the Pohlé process of raising water from non-flowing artesian wells, mines and other sub-surface sources.

The pump proper consists of only two plain, open-ended pipes, the larger one with an enlarged end-piece constituting the discharge pipe, and the smaller one let into the enlarged end-piece of the discharge-pipe constitutes the air inlet pipe, through which the compressed air is conveyed to the enlarged end-piece on the under side of the water to be raised, when this combination of pipes is lowered into the water of the well. No valves, buckets, plungers, rods, or other moving parts are used within the pipes or well. It is, therefore, obvious that, where there is no moving mechanism, no obstacle to the free movement of water is interposed, and the full area of the pipe becomes available.

As the pump has no valves, no standing water remains in the pump column after the operation of pumping ; it recedes into the well, and there is none left to freeze in cold weather.

At the beginning of the operation, the water surface outside of the pipe and the water surface inside of the pipe are at the same level, hence the vertical pressures per square inch are equal at the submerged end of the pipe, outside and inside.

As soon as air is forced into the lower end of the tube it forms alternate layers with the water, so that the pressure per square inch of the column thus made up of air and water, as it ascends in the interior, is less than the pressure of water per square inch outside of the pipe. Owing to this difference of pressure, the water flows continually from the outer to the inner side by the force of gravity, and its ascent through the pipe is free from shock, jar, or noise of any kind.

These air sections, or strata of compressed air, form water-tight bodies, which, in their ascent in the act of pumping, permit no "slipping" or back flow of water. As each air stratum progresses

upwards to the spout, it expands on its way in proportion as the overlying weight of water is diminished by its discharge, so that the pressure, which may have been, say, 50 pounds per square inch at first, will be only 1·74 pounds when it underlies a water layer of four feet in length at the spout, until finally this air section, when it lifts up and throws out this four feet of water, is of the same tension as the normal atmosphere ; thus proving that the whole of its energy was used in work, and that the pump is a perfect expansion engine.

As the weight of the water outside of the discharge pipe (the head) is one-third greater per square inch than the aggregate water sections within the pipe when in operation, it follows that the energy due to this one-third greater weight is utilised in overcoming the resistance of entry into the pipe, and all the friction within it.

The Pohlé "Air Lift" Pump gives ninety per cent. of efficiency from the air receiver in water pipes of large diameter, and in smaller ones usually over 80 per cent., retaining it without repairs until the pipes rust through, whereas ordinary bucket and plunger pumps gradually lose efficiency from the first stroke they make, and more rapidly if the water contains sand or is acid in character.

The *capacity* of the pump is unlimited, and, with the proper proportions of air to water, will work excellently in pipes several feet in diameter. Estimates have been made which indicate that a 30-inch pipe will deliver 16,660 gallons per minute, equal to 1,000,000 gallons per hour.

It has been estimated by competent experts, that, under favourable conditions with large diameters of water and air pipes, 1,000,000 gallons of water can be raised 100 feet high with one and a half tons of good coal.

As sand, silt, culm, gravel and boulders in water form no obstacles interfering with the action of the pump, its adaptability for dredging is suggested, as well as its utility for raising sewage. Experience has proved that, by the use of this constant upward flow of water, artesian wells have been freed from their accumulated sedimentary deposits, as well as that lodged in the fissures and crevices of their wall rock, and have been thus made to yield greater quantities of water than they ever did before.

For chemical uses, and for the liquids of the arts, there is no method superior to the "Air Lift." It is used successfully for raising sulphuric acid of high specific gravities, and is well adapted for almost every other pumping work.

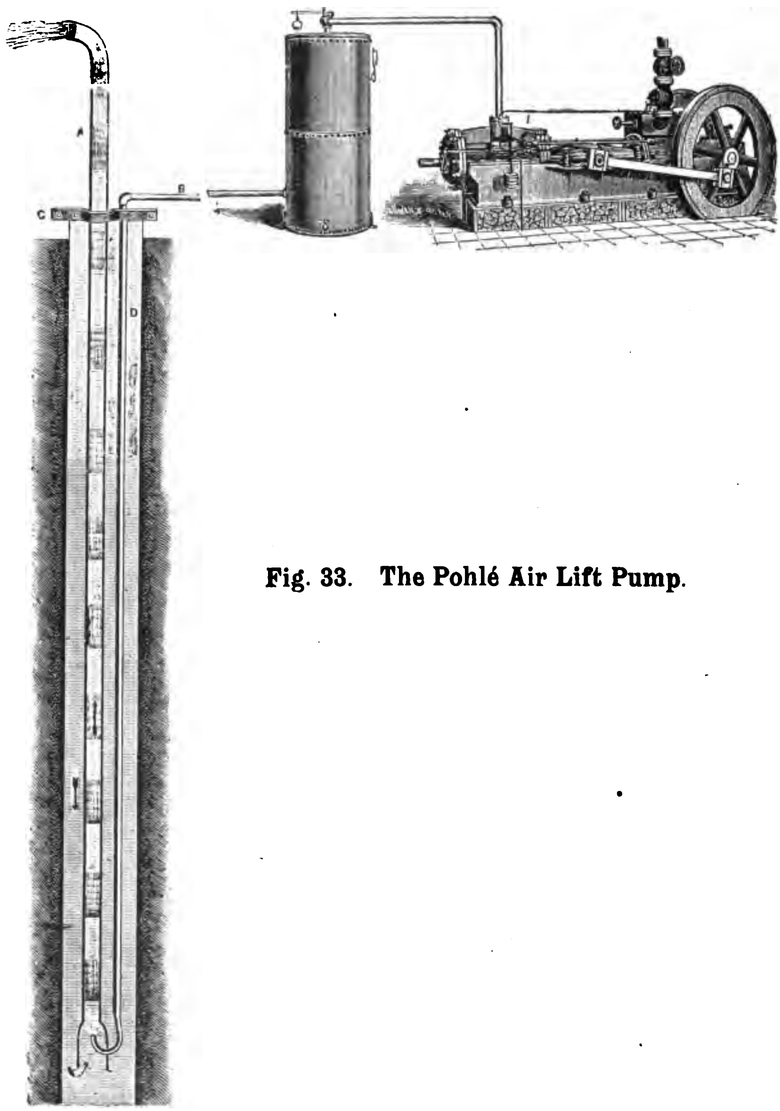


Fig. 33. The Pohlé Air Lift Pump.

Vertical Compound Cornish Pumping Engines.

This engine has what is termed the Cornish cycle of steam distribution, *i.e.*, each of the two cylinders is single acting, and on steam being admitted to the under side of the high and upper side of the low pressure piston, a weight of pump-rods is raised, which, when allowed to fall again into the pit, is sufficient to overcome the pump resistance without any help from the engine. To effect this return or outdoor

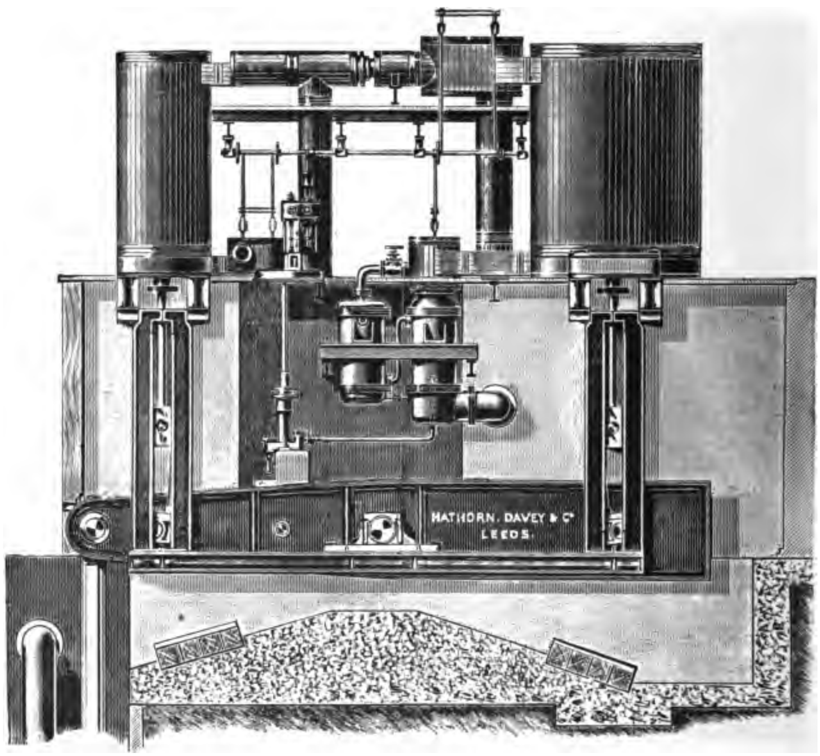


Fig. 34. Compound Differential Cornish Pumping Engine.
To raise 120 gallons per stroke from a shaft 1 000 feet deep.

stroke, the pressure on either side of each piston is put into equilibrium by opening valves uniting the upper and lower ends of each cylinder. No change, therefore, occurs during this stroke in the quantity of steam contained in the cylinders, a simple transfer to the opposite side of each piston being all that takes place, while on the succeeding indoor stroke, the steam thus transferred passes to the low pressure cylinder or to

exhaust. Therefore, by using this cycle, the steam end of the high pressure cylinder is never brought into direct communication with the low pressure, or the steam end of the low pressure cylinder with the condenser, thereby reducing cylinder condensation to a minimum.

These engines being compound, are able to utilise the high steam pressures now available, and also strain the pump-rods far less than a single cylinder engine would do; for not only does the compound engine take up its load more gradually, but also the disproportion between the initial and the normal strain on the pump-rods is much less with the compound than with the single cylinder engine. For if it is attempted to get a high degree of expansion with one cylinder only, cut-off must take place very early in the stroke and the momentum, and therefore the velocity of the moving parts must be great, with the result that the initial strain is very greatly in excess of the normal load, a matter of very great importance, particularly in deep mines.

For the above reasons these compound Cornish cycle engines give a better coal economy than ordinary Cornish engines. On the other hand, as the cylinder area is, of course, twice that of a double-acting engine of the same power, the weight and cost are both increased.

Motion is transmitted to the pumps by means of a balanced beam placed beneath the cylinders. The latter are carried on girders built into the engine pillar, and also tied to and strutted from the girders supporting the main beam gudgeons. The whole arrangement is therefore extremely rigid.

Two-throw and Three-throw Vertical Ram Pumps.

Two-throw, belt-driven, ram pumps are especially suitable in cases where power from existing line shafting is available, and where it is required to raise small quantities of water to a moderate height. They are compact and inexpensive, with few working parts, and those both strong and easily accessible.

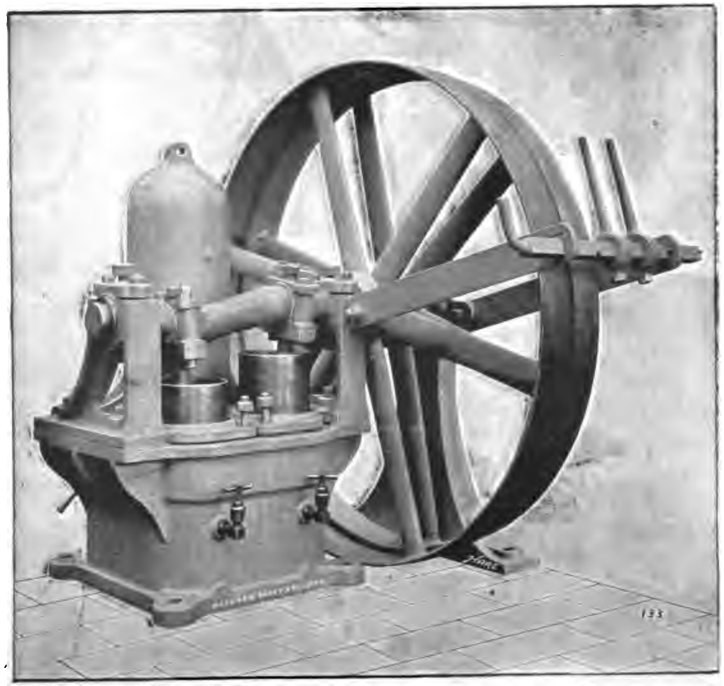
The Smith form consists of a bed-plate and pair of rams, provided with valve boxes, air vessels, and connecting pipes both on the suction and delivery, and complete with fast and loose pulley and belt-shifting gear. Fig. 35.

The Inge is of a similar pattern, except that the rams are placed within the standards and are driven by a double web bent crank, the pulleys being carried on the outside of the frame. Fig. 36.

Either one can be driven by gearing and countershaft.

Fig. 36. Two-Throw Ram Pump.

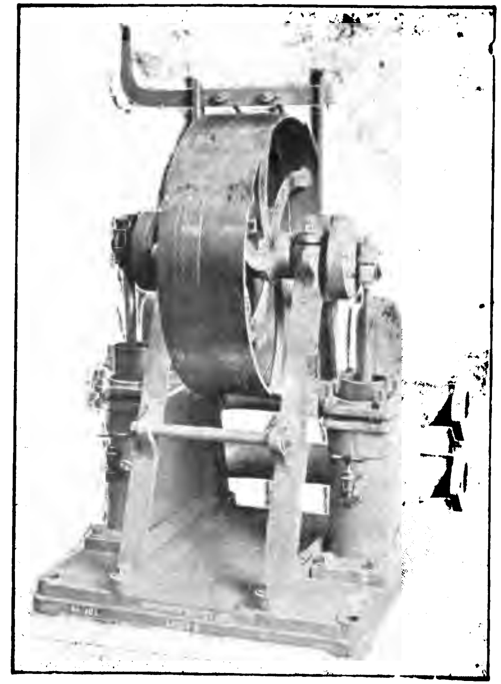
INGE TYPE.



To raise 3,600 gallons per hour 60 feet high.

Fig. 35. Two-Throw Ram Pump.

SMITH TYPE.



To raise 1,300 gallons per hour 30 feet high.

The Inge pump is also made in the three-throw style, which, as giving an exceedingly constant resistance, is the most suitable when it is desired to drive from an electric motor. Power can be transmitted from the latter either by belting or by gearing; in the latter case the bed-plate supplied is made of sufficient extent to carry the motor.

Hydraulic Pumps.

In cases where it is not desirable to take either the rods or steam down the mine, the combination of a steam pumping engine on the surface, supplying driving-water under pressure, with the hydraulic gear below ground, is perhaps the best that can be adopted.

Use of Hydraulic Power for Driving.

When a pit has been sunk, and workings are carried out along the dip of the seam, cases frequently arise in which, although adequate plant is provided in the main shaft, it is necessary to find means of raising the water made in the dip workings to the shaft foot.

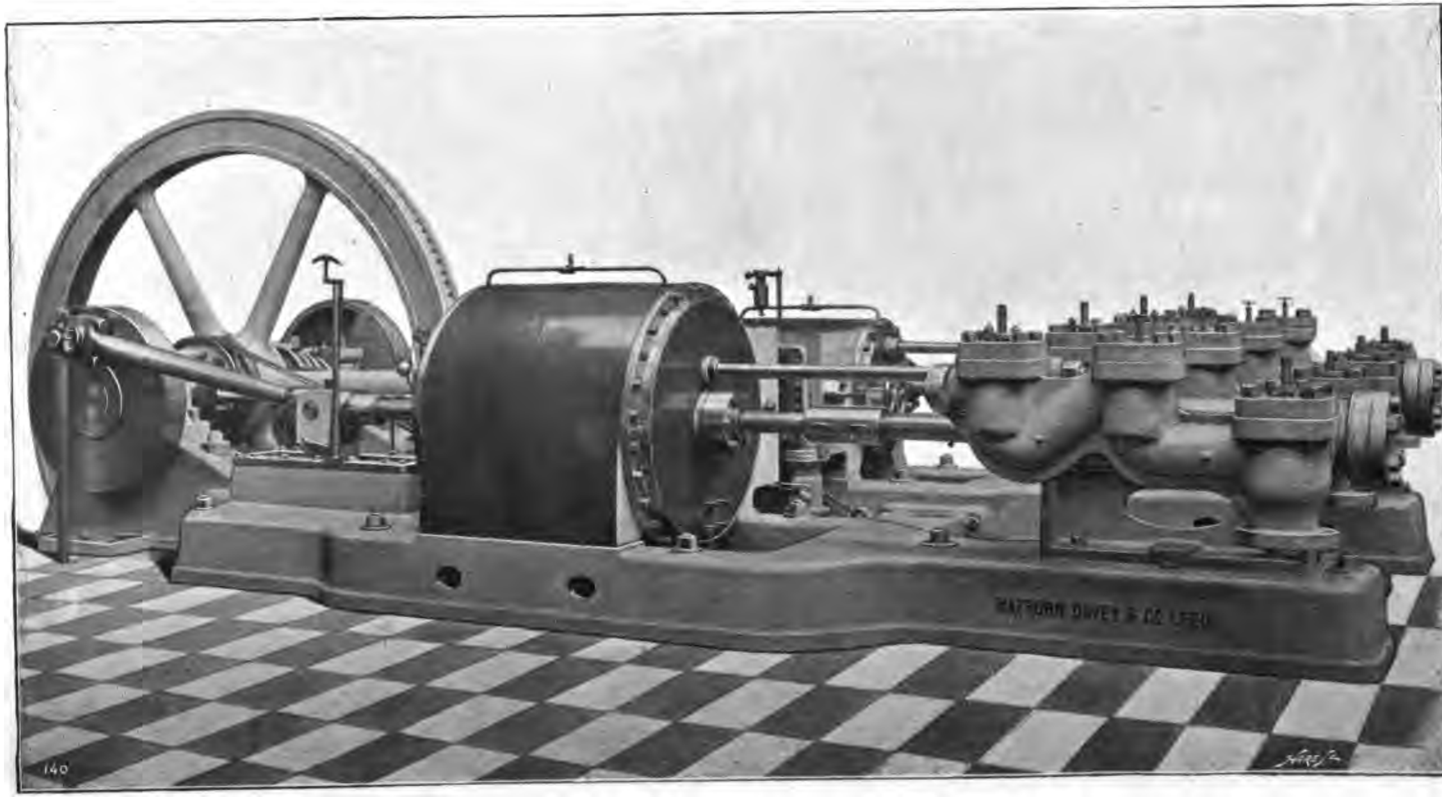
Hydraulic pumps are specially designed to meet such cases.

These are driven by water taken from the foot of the rising column of the main pumps. This water, after use, is returned along with that which is lifted to the main sump. See diagrammatic arrangement on pages 232, 233.

The system is simple and safe, takes little room, and involves only a very small cost for attendance and up-keep, it is strongly recommended in all cases where the main shaft pumps have a sufficient margin of capacity.

Mr. Stuart McMurtrie, of the Radstock Collieries, gives in *Mining Engineering*, January, 1898, the following particulars as to his experience with a double-acting arrangement of this class :—"The duty for which this pump was sold was to raise 25 gallons of water per minute a vertical height of 870 feet, through 870 feet of pipes 3½ in. in diameter, with a gross driving head of 1,730 feet through 1,730 feet of 3 in. pipe. The diameter of the pump ram is 5 in., and the stroke 1 foot. 10 double strokes is the speed at which the pump works regularly, but it has been run at double that number, and also at a much slower speed.

Fig. 37. Hydraulic Pump.



Compound Accumulator Engine for the Mersey Docks. To force 320 gallons of water per minute against a pressure of 780 lbs,

	£	s.	d
Capital Costs:			
Pump complete	125	0	0
Steel pipes and valves	150	10	1
Sundries	9	10	4
Labour of erecting pump and pipes	63	17	4
Labour of a skilled man to superintend erection	5	15	0
	£354	12	9

The writer has estimated the present cost per annum for attendance and general maintenance of the pump to be :—			
Attendance, 2s. 6d. per week × 52	6	10	0
Repairs to valve boxes	5	0	0
Hydraulic leathers for valves (two pairs, twice annually)	1	11	0
Glands (graphite packing, once annually) ...	0	16	0
Tallow, 1 lb. per week	0	10	10
Labour of packing	0	7	3
Extra cost of pumping at Tyning	130	17	4
	£145	12	5

While below is the actual former cost of winding the water :—			
Winding engineman and stoker's wages ...	54	12	0
General repairs to engine and boilers	7	8	0
Cleaning boilers	3	12	0
Shaft examination	1	16	0
Repairs to cages and water tanks	1	6	4
Coal for boilers	124	16	0
Haulage of coal for same	15	12	0
One new cage every four years, £16 13s. 4d. ÷ 4	4	3	4
One new rope every three years, £38 10s. ÷ 3 ...	12	16	8
Oil and other stores	7	15	2
Annual saving, £88 5s. 1d.	£233	17	6

In estimating the cost of winding the water, maintenance of the wooden guides has been ignored.

In conclusion, the writer may remark that the pump has worked most successfully."

Single-Acting Hydraulic Pumps.

The single-acting pump is rather less in first cost than the double-acting duplex. It is besides lighter and occupies less space, and where only small quantities of water are to be dealt with is a very convenient form.

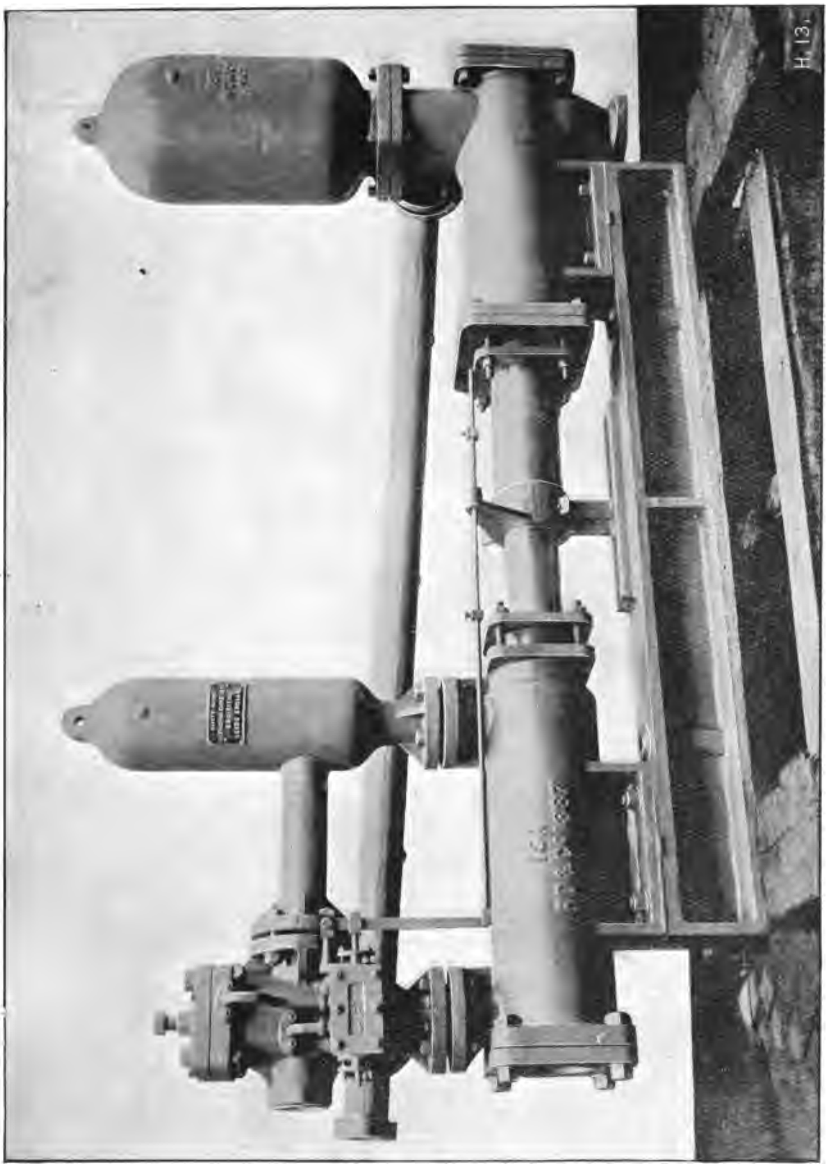
Although it is entitled single-acting, the flow through the delivery pipes when, as is usually the case, the exhaust water is delivered along with the mine water pumped, is fairly constant, on account of each of the foregoing being delivered on alternate strokes, while as the power cylinder is built on the piston and plunger type, the water it gives is used on both strokes, so that the flow here is also of a fairly continuous character.

It is constructed on the pump side with a single-acting plunger, and on the power side with a piston and plunger, the barrel in which the latter works being brass-lined.

As in the case of the duplex, the valves serving for admission and exhaust of the driving water are made to close by dropping on to mitred seats instead of, as in some designs, sliding over ports. They are, therefore, particularly suitable for handling mine drainage containing grit. Also, they are so arranged that the exhaust valve can only be opened after the admission valve has closed, thus preventing the risk of power water passing to exhaust without doing its proper work in the pump.

Fig. 38. Single-Acting Hydraulic Pump.

For the Indian State Railways.

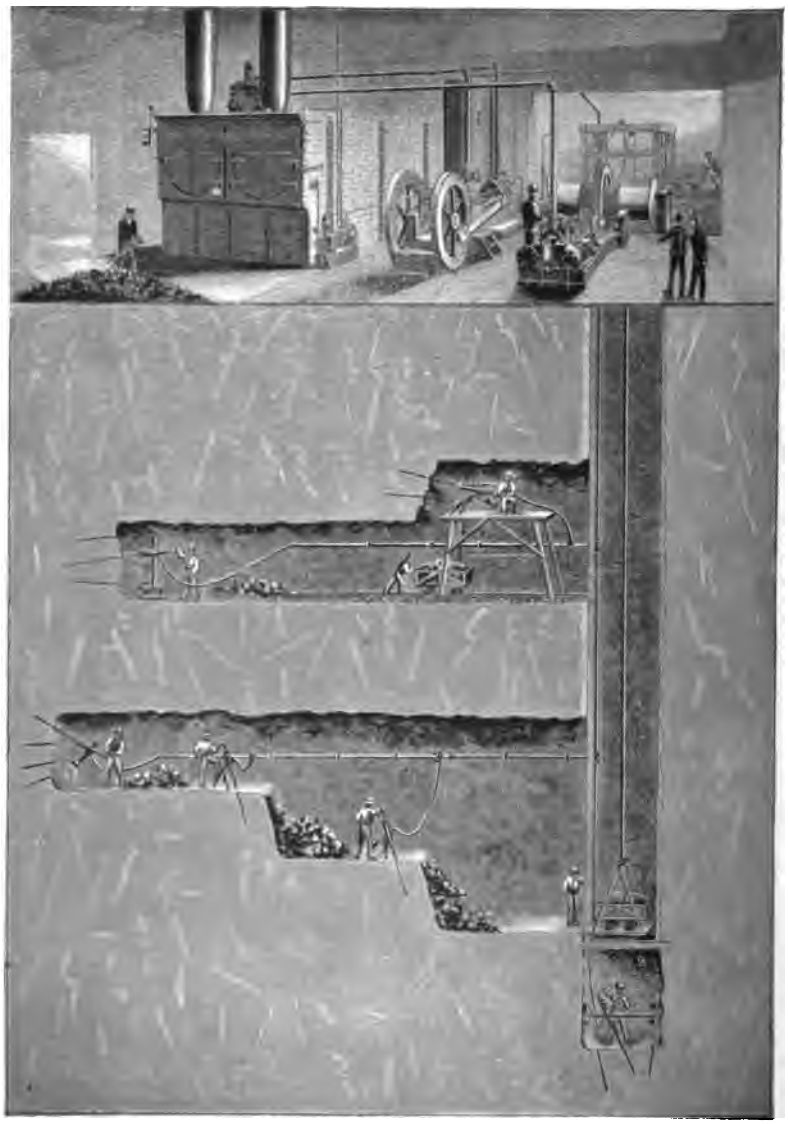


To raise 20 gallons of water per minute 60 feet high.

Machinery for Light Shaft Sinking.

In Fig. 39 is illustrated plant used in shaft sinking, where the material to be passed through requires drilling and blasting.

Fig. 39. Ingersoll-Sergeant System.



ELECTRICITY
in
MINING.

ELECTRICITY IN MINING.

Electricity in mining has made rapid and substantial progress, and it is not now a question of whether it pays to put down a plant, but what system is best suited to the conditions of the particular mine under consideration.

In order to obtain the greatest commercial efficiency with simplicity of working, care should be taken in the design and construction of the generator, motor, cables, starting rheostat, safety fuses, &c., to suit the necessities of fiery, damp, or dusty mines.

For the transmission of power over long or short distances electricity is, in nearly every instance, both the cheapest in first cost, and the most efficient and convenient method. A comparatively small and flexible cable is employed to convey the current from the dynamo, which may be situated many miles from the motor. The loss in the cable, moreover, for a given length, is much less than in the case of steam or air, in which condensation and leakage are usually serious items. An electrical efficiency of 70 to 80 per cent. can be easily obtained.

For the transmission of electrical energy over moderate distances, the continuous current system answers every purpose.

In some cases it is both convenient and commercially desirable to drive motors from the same dynamo as is employed for lighting purposes, but for larger powers it is advisable to use a separate dynamo wound for a suitable voltage, as by this means the loss in transmission may be considerably reduced. When only one motor has to be driven from one dynamo, a series-wound dynamo driving a series-wound motor, forms a perfectly self-regulating arrangement, but where more than one motor has to be driven it is necessary to employ a compound-wound dynamo.

A shunt-wound motor, when supplied with current at a constant voltage, will maintain nearly constant speed with any load up to the maximum, the power absorbed being proportional to the work done. Shunt-wound motors are most suitable for driving machinery which starts under a light load and has to run at a constant speed, such as fans and machine tools.

For driving machinery which has to be frequently started and stopped, as, for instance, main and tail rope haulage, it is advisable to

have a shunt-wound motor, and to keep it always running, the starting and stopping of the rope being done by means of a suitable friction clutch.

Series-wound motors, which have a maximum torque at starting, are specially suitable for driving machines obliged to start under a heavy load, as in pumping, hauling, &c.

It is most important that both dynamo and motor should be of ample power for the work required, and in choosing a plant it should be remembered that electrical, like all other machinery, is more efficient the nearer it is kept to its full load, so that the advisability of putting in two or more smaller machines in the place of a large one should be carefully considered, provision being made on the switch-board for coupling the machines electrically as the load increases.

For transmitting electrical energy over very long distances, the alternating current system offers some advantages, which consist mainly in the ease with which the current can be transformed at the generating station from a low voltage of, say, 100 to 200 volts, by means of a stationary transformer to 1,000 to 10,000 volts, at which pressure it can be transmitted through a comparatively small and inexpensive cable over long distances, and again transformed at the distant and intermediate stations to a suitable voltage.

In addition to the above-named advantage, alternating current motors, constructed on the 3-phase system, whilst being self-starting, are free from any sliding contacts, commutators or brushes, and are, consequently, non-sparking.

Alternating current dynamos may be used for lighting in the same manner as continuous current machines.

The appliances we shall describe were in many instances originally invented for obtaining coal, but are also adapted to the mining of potash salts.

Fig. 40. Electric Pumping Plant.

By Messrs. John Davis & Son (Derby), Ltd.

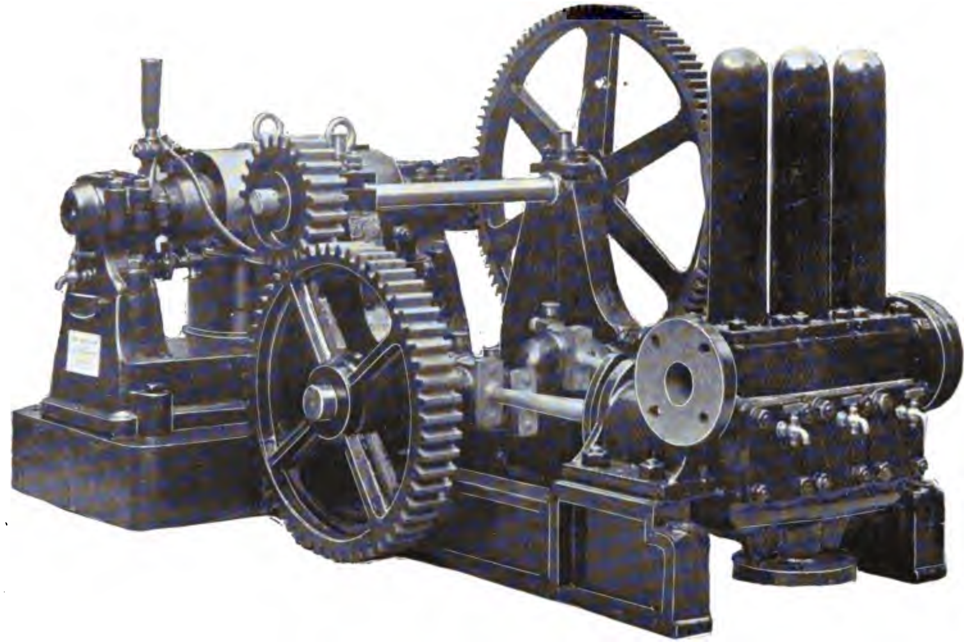


ILLUSTRATION OF A 3-THROW 3 IN. BY 3 IN. PUMP COUPLED DIRECT TO AN ELECTRIC MOTOR.

Fig. 41. Electric Main and Tail Rope Haulage.

By Messrs. John Davis & Son (Derby), Ltd.

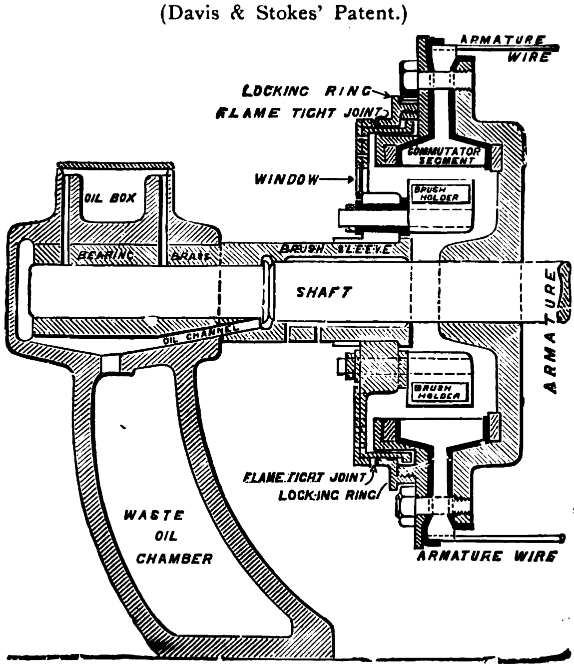
The illustration shown above represents a main and tail rope electric haulage plant. The motor, which is of 40 break horse-power, is geared to the first motion by means of an endless belt; the second motion is geared by spur wheels to the main drum shaft; each drum is provided with a special friction clutch, by means of which either one can be put in or out of gear without stopping the motor, thus relieving it of the sudden shock consequent upon starting against a heavy dead load.

The motor is provided with special improved mining starting switches, combined with resistance of large cooling surface, the switch being arranged to automatically reduce sparking to a minimum when the circuit is broken, thus doing away with the destructive spark generally found in connection with electric power plants where this arrangement is not in use. This plant hauls a train of 15 loaded tubs up an incline of 1 in 5 at the rate of seven miles per hour, and such is the simplicity of manipulation that the ropes do not stand idle for more than a few seconds between each journey, with the result that, whilst working at the greatest commercial efficiency, the output of the pit from the one district has increased over 200 tons per shift.

The generator is situated on the surface, half a mile away, and also supplies energy for an endless rope haulage system and electric cutters.

Fig. 42. Safety Commutator for Dynamos and Motors in Fiery Mines.

(Davis & Stokes' Patent.)



SECTION OF SAFETY COMMUTATOR.

To enable direct current motors to be employed in fiery mines, and to obviate the danger of sparking at the brushes, which might cause the ignition of gas, many attempts have been made and have generally taken the direction of enclosing either the whole or part of the machine.

These arrangements introduced difficulties in the ventilation of the armature, and necessarily included a considerable air space, so that when this space became filled with gas an explosion might take place inside the case of such violence as to entirely destroy the cover, and communicating with the atmosphere, cause an explosion outside.

The arrangement illustrated is so constructed that the commutator itself is practically equivalent to a locked safety lamp enclosing the brushes, since it cannot be opened while running; the junction between the fixed and the revolving portions of the machine being made by a flame-tight joint.

Referring to the sectional illustration, it will be seen that the most marked deviation from the ordinary commutator is, that instead of the brush contact being on the outside of the commutator segments the brushes bear on the inside face.

The method of construction is as follows:—The commutator segments are clamped between a ring and a disc, the latter being keyed on the shaft.

The disc forms a closed end to the commutator at the side nearest the armature. The brass journal of the shaft is extended nearly up to the disc, leaving room for a slight end play (the shaft, of course, only bearing in the usual portion of brass), and means are provided to restrain the lubricating oil from working along the extended portion of the brass and entering the commutator. The end of the commutator is closed by a disc sliding on the extended brass bearing and carrying the brush holders and brushes; and a clamping handle provides for setting the disc and brushes in their proper position. This disc, as stated, closes the end of the commutator, the latter revolving with a clearance of $\frac{1}{32}$ in.; a locking ring is interposed to prevent the disc, with its brushes, being withdrawn while the machine is running, or to obviate its being started before properly closed.

Small windows are provided in the disc, by which any sparking at the brushes can be seen and corrected, and the brush holders are fitted with springs working on the outside of the disc, for adjusting their pressure while running.

Fig. 43. Electric Longwall Cutter.

By Messrs. John Davis & Son (Derby), Ltd.

Length, 8 ft. 2 ins. Height, 19 ins. Width, 3 ft. 8½ ins.

Depth of Holing at floor level, 3 ft. to 6 ft. Width of Kerf, 4 ins. to 9 ins. Standard Voltages, 500, 220.

The illustrations, Figs. 44 to 46, reproduced from photographs taken at the face of the seam, show the latest design of longwall cutting machinery. It will be noticed that it is a disc machine and self-propelling ; these two features are common to most machines of its class.

The novel features are :—

1.—That it runs on one rail only, the side thrust being taken by special sleepers and light screw jacks. The use of one rail overcomes the trouble of rail jumping, so common where two rails are employed.

2.—It cuts its own floor, *i.e.*, cuts actually at floor level, but can be built to cut any height up the seam.

3.—The cutting wheel may be tilted up or down by means of a hand wheel, so that serious obstacles, if met with in the holing, may be ridden over or loosened, or on an uneven floor the irregularities may be followed.

Fig. 44. Rear View.

4.—The machine is constructed to be driven from the front end ; this enables the attendant to lay his rails and see that the face and roof are safe before the machine approaches, and, moreover, leaves more room at the rear for the timber man to follow with the props required,

It is, however, constructed to cut in either direction—that is to say, forwards or backwards, thus saving the labour of moving it when only short faces are available, or when the roof will not admit of long faces being worked.

5.—The feed is driven by an eccentric at the rear of the machine through a ratchet and pawl on to the haulage drum ; the novelty at this point consists in the arrangement which enables the feed to be stopped, started, or adjusted without it being necessary to stop the motor. This is important, as it enables the machine to clear itself should it become

Fig. 45. Side View.

clogged by a fall of rock. Three rates of cutting are provided—8, 16 and 25 inches per minute—thus adapting the same machine to hard or soft material.

6.—The haulage drum is provided with a friction clutch, which in the event of excessive strains, slips and eases the machine.

7.—The entire apparatus is made of steel, and the gear wheels accurately machine-cut. The high-speed gearing of the armature as well as the cutting wheel and feed eccentric is enclosed in a casing arranged so as to be run in oil. This gearing has had special attention

—in the first place, to reduce the wear and tear, and secondly, to lessen the noise ; the result being an enormous increase in the life of the gear wheels and such silence in running that the movements of the material can be heard whilst the machine is cutting.

Fig 46. Front View.

The electric machine is 8 feet 2 inches long, 3 feet 8½ inches wide, and 19 inches high ; it cuts from 3 to 6 feet under, making a kerf of 4 to 9 inches.

The motor is free from sparking, the starting switch is completely enclosed, and the connections from the trailing cable to the machine enclosed with a metal cover.

Electric Chain Heading Machine.

CUTTING 5, 6. OR 7 FEET DEEP BY 39 OR 44 INCHES WIDE.

STANDARD VOLTAGES, 500 AND 220.

The Heading Machine, as will be seen from the illustration, 47, 48 and 49, is a breast machine, making its cut straight to the front.

The principal parts are three in number :—

1.—The bed frame, which is the stationary part, being jacked both front and rear to the face and roof.

2.—The sliding chain cutter frame, as its name implies, slides on the bed frame and carries the revolving chain in which are fixed the knives.

3.—The motor carriage supporting the motor and gearing, and attached to the sliding frame by steel castings.

The motor is of the multi-polar steel-clad type, is constructed to perform the most severe duties to which a machine of the kind can be subjected, and has a high efficiency. The frame is of cast steel and the armature of the ironclad form—that is, the wires are embedded in the core of the armature, which gives the maximum mechanical strength and ensures freedom from damage. The commutator is made of the best quality hard drawn copper of ample capacity. There is no sparking, and the increase of temperature is exceedingly small.

All the bearings are of bronze. The chain carrying the cutters is made of cast steel solid links, coupled together with drop forged straps, having lugs at each end, which provide bearings for the cutter links.

This construction enables the chain to be taken apart and replaced in a very short time. The bits are straight, with a slight hook at the cutting end, and are so shaped that they can be re-sharpened many times, allowing about 75 per cent. of the steel in each bit to be used.

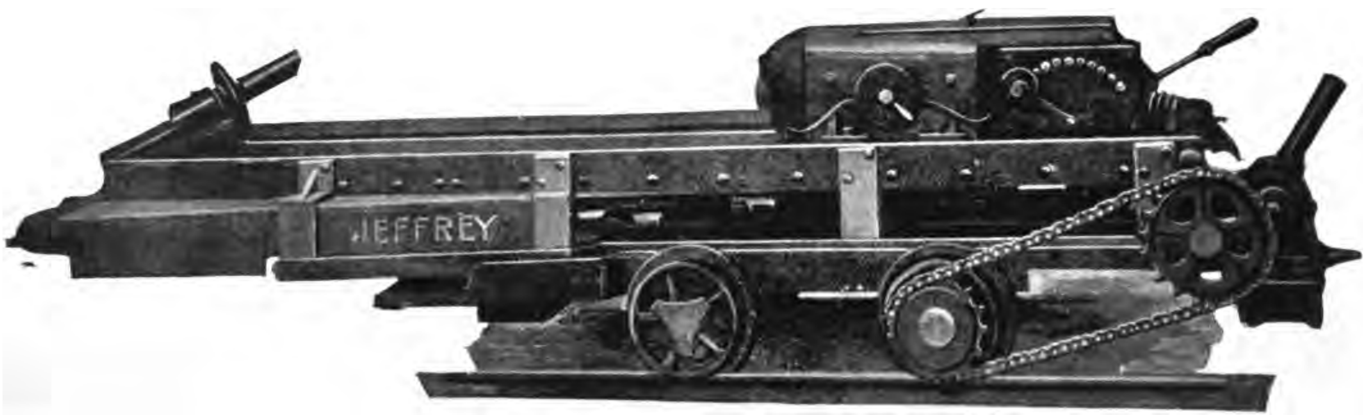
The cutter-head is bolted together, and can be readily taken apart; to the corner of it is attached an idler, on which the cutting chain runs, and in order to provide for an ample supply of oil to these, a double bearing is used which allows space for packing, thus providing a constant lubrication.

The machines are built to undercut 5 feet, 6 feet and 7 feet, the width of each cut being either 39 inches or 44 inches, with a kerf of 4 inches. All parts are built to template, and in case of accident can be replaced with little delay. The self-propelling truck is a valuable addition to the machine where heavy grades are to be encountered. This truck converts the machine into a locomotive, and causes it to propel itself from point to point, and by means of a reversing switch on the motor it can be run in either direction. The motion is imparted to the truck wheels by means of a chain and sprocket; this method of propulsion is being used in mines pitching from 12 to 15 degrees. The truck itself is entirely of iron, and is strongly and compactly built.

The *modus operandi* is as follows:—The machine, mounted on its truck, is hauled to the face of the seam, the truck running on the rails used for the mine tubs, the rear end of the truck is lifted, and the

Fig. 47. Electric Chain Heading Machine.

Fig. 48. Mounted on Self-propelling Truck.



machine slides off, reaching at once its proper position to commence cutting. Connection having been made with the cable, and the frame firmly jacked, the machine is ready to start. The operator generally remains at the rear of the machine, his work being practically at an end until the machine has finished its cut. He then reverses the gearing by means of a lever, and the cutter frame travels back until it reaches a point where it is automatically thrown out of gear. The machine is then ready to be moved for its next cut, which can be readily done by two men, by means of crowbars, the front end sliding on its own shoe boards, the rear end on the skid boards provided for the purpose. In addition to the operator, one other man only is required, to set the front jack, help shift the machine, and shovel out the slack. After the length of a face has been holed, the machine is again placed on its truck (this is easily accomplished by the two men in charge by means of the winch on the truck). A horse then takes it to the next stall or face to be holed, or for steep gradients a self-propelling truck is provided.

The average time occupied from the commencement of one cut to the beginning of the next is from five to eight minutes, varying with the hardness of the rock, the depth of cut being up to 7 feet by 39 inches or 44 inches wide, about 4 inches in height being removed. The machine will cut equally well in fire-clay, clench, or coal.

The average horse-power absorbed, as taken from a large number of readings in coal of varying hardness, works out at about 12. These machines are extensively employed for pillar and stall and heading work, and in many pits are doing good service in longwall work where the floor and roof are good.

Mr. Wm. Miller, Manager of the Equitable Coal Company, Limited, Deshergur, has given the following report upon the Jeffrey coal-cutter Fig. 48, which will doubtless prove interesting. It will be seen that one machine can produce 190 tons per day of 24 hours, or four times that produced by hand labour from an equal number of galleries :—

"This machine has now been at work for a period of nine months, but during the first four months of that period it was only worked one shift of eight hours, afterwards for one month it worked two shifts of eight hours, and for the last four months it has been worked three shifts of eight hours. My remarks apply principally to the two months' working ending 31st March, for which I have been able to compute the quantity of coal undercut and to average cost per ton. During the two months mentioned the machine undercut a total of 4,232 tons, at an

Fig. 49. Electric Chain Heading Machine.

MOUNTED UPON SELF-PROPELLING TRUCKS.

average cost of one rupee per ton (I may state this cost can be reduced, as the quantity of work done during the two months was not nearly up to the capacity of the machine). The cost includes all labour (European or native) employed on the machine ; also drillers, loaders, trammers, &c., together with all blasting materials, stores, &c., necessary for the working and keeping of the machine and the whole of the electric plant in repair.

"The advantages of this machine may be stated as follows :—

"1.—Its working cost per ton of coal undercut is very favourable, compared with hand labour.

"2.—A large output can be got from a small working area, *i.e.*, from a very few galleries. Twelve galleries are sufficient to keep one machine working and cutting six per day. Therefore, 12 galleries can be made to give 190 tons per day, against about 48 tons from the same number of galleries working by hand labour, or four times as much.

"3.—It economises labour at least 50 per cent. Very few skilled miners are required, only for such work as drilling, blasting and dressing. Any class of labour can be employed to load and tram the coal ; thus the miner is left available for other coal cutting.

"4.—The machine is easily handled and fixed in position. Six natives, with a supervisor (European or native) only employed in working and shifting the machine about.

"5.—The machine undercuts the coal with great ease and rapidity. One cut three feet wide and six feet deep can be made in from three to four minutes after the machine is fixed. Two galleries, each with four cuts three feet wide and six feet deep, have been undercut in eight hours, including shifting the machine from gallery to gallery, and fixing it in position for every cut.

"6.—Two galleries undercut in a twenty feet seem (but allowing only seventeen feet of coal in height to be cut) in eight hours will make six galleries in twenty-four hours. Six galleries undercut twelve feet wide by six feet deep and seventeen feet high gives a total of 264 tons undercut in the 24 hours. From this quantity 25 per cent. should be deducted, to include stoppages for repairs and other various causes. The capabilities of the machine may, therefore, be safely stated at 190 tons undercut daily ; or, in round figures, 5,000 tons monthly, under the conditions already mentioned. The quantity undercut will, of course, be correspondingly less or more according to the thickness of the seam. It should also be stated that the number of galleries undercut

will depend on the gradient of the seam. In our case it is one in five. In a flat gradient the machine should exceed the above very considerably, as the greatest part of the time is spent in moving the machine, especially up the gradient when it is steep.

"My experience of the working of the Jeffrey machine has been very favourable, and I can highly recommend its adoption in any colliery where labour is scarce, gallery room limited, and increase of output desired at the lowest minimum cost.

"I can further highly recommend the two electric drilling machines. These machines are light, easily handled and fixed, and drill a hole five to six feet deep in less than a minute. This machine facilitates the blowing of the coal and the preparing of the galleries for the coal cutter."

Mr. T. Williamson, of The West Hallam Colliery Co., Ltd., says :— "We find the Jeffrey heading machine of great service in opening out, and consider it mechanically and electrically very strong. It has given us no trouble whatever."

Mr. W. Hay, Manager of Messrs. J. & N. Nadin & Co., says :— "The Jeffrey electrical coal heading machine, which you supplied to us, has driven 1,100 yards of heading, and with the exception of a few slight stoppages has worked very satisfactorily. Electrically, I consider the machine pretty nearly perfect."

"*Mr. John Morrison, Manager of the Newbattle Colliery, Dalkeith*, reports that the Jeffrey electrical coal drill is working there with very satisfactory results, making a hole about 4 feet deep in hard splint coal in the space of five minutes, including the setting of the drill. This, he adds, is equal to the work of four men, and only one man is required to work the machine, which is driven by compressed air."

Mr. W. S. Gresley, of the Youghiogheny River Coal Co., Pittsburgh, in his paper communicated to the Institution of Civil Engineers, on "Central Station Electric Coal Mining Plant in Pennsylvania, U.S.," where he has sixteen electric coal cutting machines under his care, says:— "All things considered, the coal cutting portion of the outfit is paying at least 50 per cent. on the original investment."

He also shows that the coal cutters produce 1½ times as much per head per day compared with manual labour, at a cost of half as much for blasting and loading, at a cost of one-eighth as much for undercutting, and at a saving of 4½d. per 2,000 lbs. of coal, with an increase of the yield of round coal.

Electric Drilling Machines.

Electric drills are very simple in construction, having few parts, and, moreover, can be operated and moved from stall to stall by one man. The machine will drill a hole 6 feet deep in less than a minute ; this and the ease with which it can be moved recommend its use in mines where much drilling has to be done.

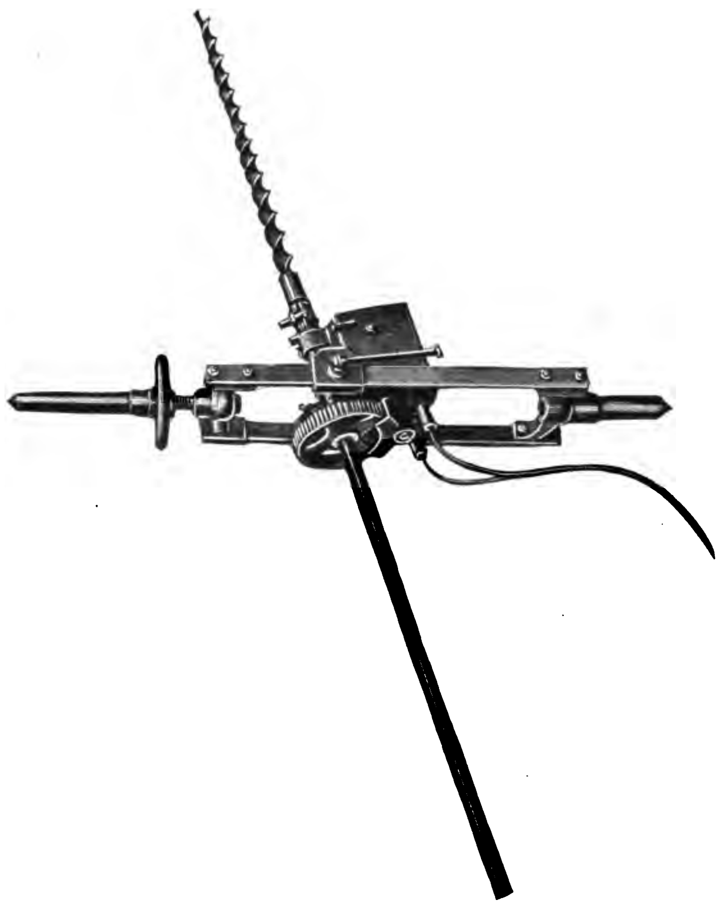
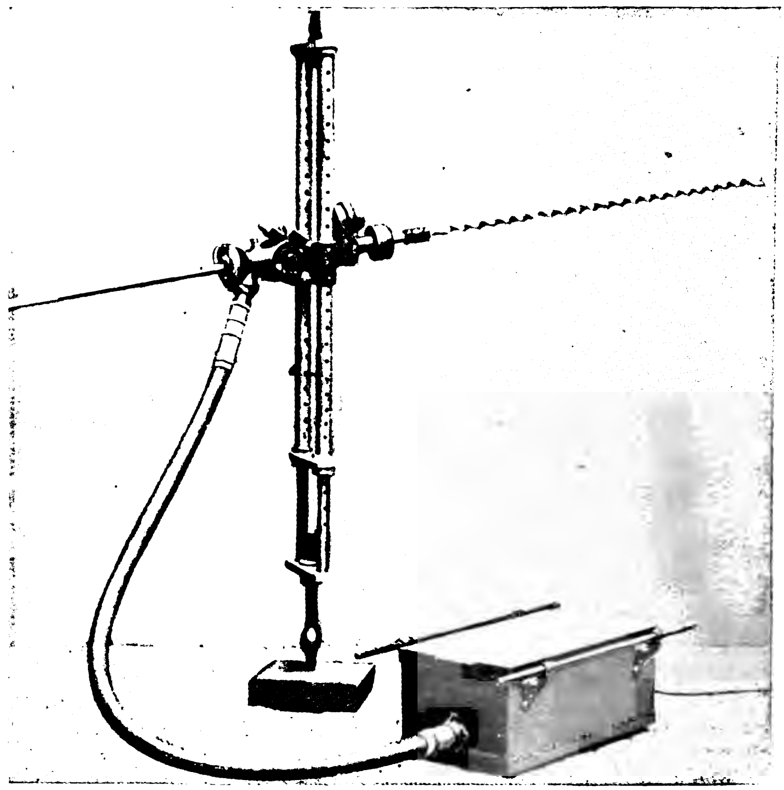


Fig. 50. Jeffrey Electric Drill.
By Messrs. John Davis & Son (Derby), Ltd.

Fig. 51. Electric Drill.



By Messrs. Siemens & Halske, Berlin.

Electric Slotting or Shearing Machine.

A machine for slotting or shearing is illustrated in Fig. 52, showing the method of supporting it while making the cut.

The method of operating is to place the machine in position on the floor, set and adjust jacks in proper position and raise machine to top of seam. The first cut being made at the top, the machine is lowered a distance equal to the cut (36 or 48 inches), and is then in position to cut again. The machine makes complete shearings from top to bottom of a seven feet seam in twenty minutes. This time includes placing it in position and adjusting jacks, the cut being 7 feet deep, 4 inches wide, and 7 feet in height. It has demonstrated its ability to operate

successfully under extremely variable conditions. During several tests, deposits of sulphur balls and sulphur bands have been encountered and passed through without injury except to some of the cutters.

Fig. 52. Electric Slotting or Shearing Machine.

By Messrs. John Davis & Son (Derby), Ltd.

The machine consists of three parts ; the bed frame, the sliding chain cutter frame, and the motor carriage. The bed frame consists of two rectangular steel channel bars and two steel angle bars firmly fastened together by means of heavy steel braces. A heavy steel casting joins the channel bars at the front end of the bed frame, and forms the gib or guide of cutter frame. At front extremity of the channel bars are rivetted two lugs for supporting the split clamp for front jack. Between the centre and the rear of the bed frame are the supports for main jacks. On each side of these supports are the bearings for truck wheels. By reference to the illustrations it will be seen that in addition to offering support for the wheels these attachments serve to make the frame more rigid. The cutter consists of one steel centre rail, a cutter head and two steel guides in which the cutter chain runs. This portion of the machine has been designed especially with respect to rigidity and minimum wear and tear, it being the part which comes in direct contact with the rock. The motor is of the four-pole type, with Gramme ring armature and two field coils. The motor frame consists of one casting forming a complete protection for the armature and field coils from water or falls of roof.

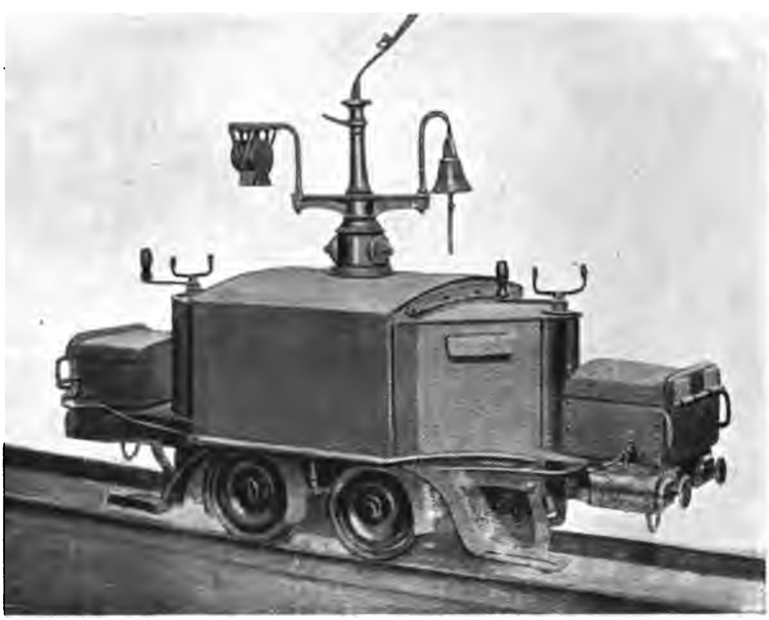
Electric Locomotives.

For collieries and works where electric power is available, electric locomotives are invaluable. These are built in various sizes, from 40 to 80 horse-power, and of various styles to suit special requirements.

Fig 53. The Jeffrey Electric Locomotive.

Fig. 53a. The Jeffrey Electric Locomotive.

Fig. 54. Electric Mine Locomotive.

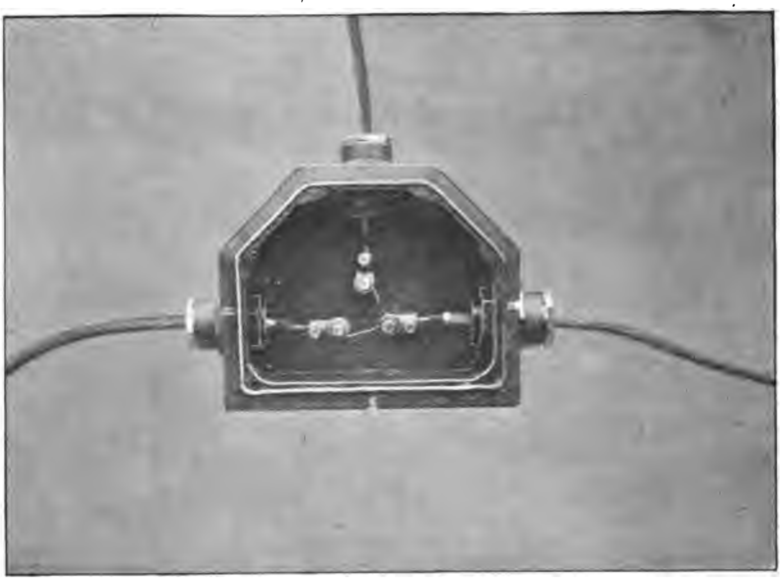


By Messrs. Siemens & Halske, Berlin.

Fig. 55. Illustration showing the Method of Supporting Bare Galvanized Iron Outer Concentric Cables.

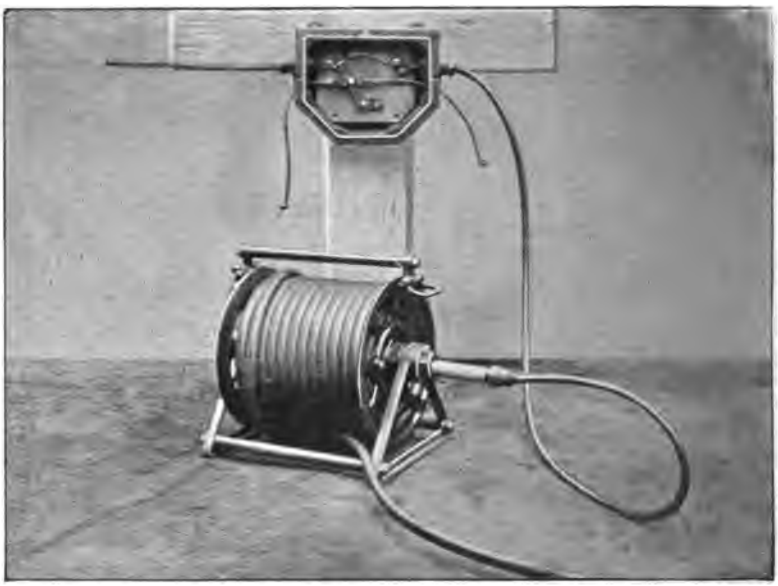
Fig. 56. Illustration of Cable Support Box in Shaft, the cable running in iron pipes.

Fig. 67. 3-Way Cast-Iron Junction and Fuse Box
(with cover removed),



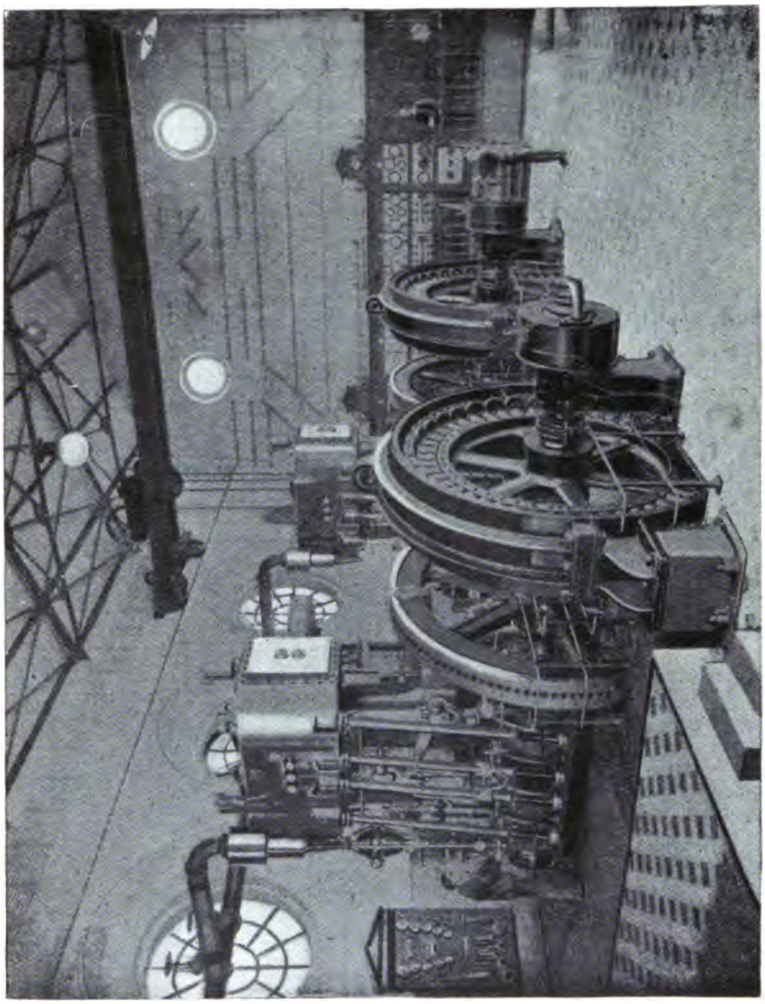
Showing method of connecting up galvanized iron outer conductor concentric or other cable.

Fig. 58.



The above shows a galvanized iron outer conductor concentric cable connected to a gate-end switch, shown without cover, from which a concentric flexible is connected to a cable reel, which is removable, so that current can be taken from the reel cable to cutting machines drills, pumps, &c.

Fig. 59. Electric Engine Hall,



at the Potash Mines, Glückauf-Sondershausen, with 3 Steam Dynamos, completed in 1899.

Fig. 60. Electric Distribution Hall,

at the Potash Mines, Glückauf-Sondershausen.

ELECTRIC BLASTING.

Magneto-exploders, whether high or low tension, are alike in their construction and principle, with the exception that the high tension machines are wound with a greater quantity of finer wire than the low tension.

Battery exploders consist of a suitable number of batteries made up in a case, with connecting terminals, and are used for low tension purposes.

Every colliery employing primary batteries should keep in stock a magneto-generator so that in case of a miss-shot, due to the deterioration or running down of the primary battery, the magneto-generator may be used, and so avoid the necessity of drilling another shot hole in dangerous proximity to the miss-fired shot.

In a high tension fuse the explosion is caused by the electric current heating a chemical compound to ignition point.

In a low tension fuse the explosion is caused by the current passing through a short bridge of fine Iridio-Platinum wire, making it red hot and firing the priming.

From the above description of the action of the fuse it will be readily seen that the explosion depends upon the existence of a proper electric circuit, both in the fuse and circuit.

The wires, though not requiring very much skilled attention, should be connected up carefully. The main points to be observed are given below :—

Having tamped the hole, separate and scrape clean the ends of the fuse wires and firing cable ; connect the fuse wires to the firing cable by twisting them together, seeing that the two wires (lead and return) are not touching each other. Fasten the fuse end of the cable so that the two wires shall not be disturbed in paying out the twin cable (a moderate-sized piece of stone laid on the cable is all that is required). When the end of the cable or point of safety is reached, connect the ends of the firing cable to the exploder terminals, and in the case of the magneto-exploder, steadying the machine with the left hand, turn the handle as sharply as possible ; when full speed is attained press the button, still continuing to turn the handle. This fires the shot. In battery exploders the shots are fired as soon as the ends of the cable ouch the terminals.

If the shots are to be fired in a very damp place, where water is liable to drop on the joints, the bare wires should be insulated with rubber tape. Special precautions have to be taken when firing under water. It is necessary to employ wires of ample carrying capacity and of good insulation.

In ordering electric fuses, the explosive employed should be stated, that the authorised detonator may be supplied. This only affects the strength of the detonator, the exploder and wire being common to all of the permitted explosives.

Low tension fuses may be tested before delivery by a special testing galvanometer.

High tension fuses can only be tested by the employment of delicate apparatus, incurring some risk of destroying the fuse.

Magneto-generators are recommended, although heavier and more costly in the first instance than primary or secondary batteries, as they maintain their power, and if properly constructed should fire an unlimited number of shots.

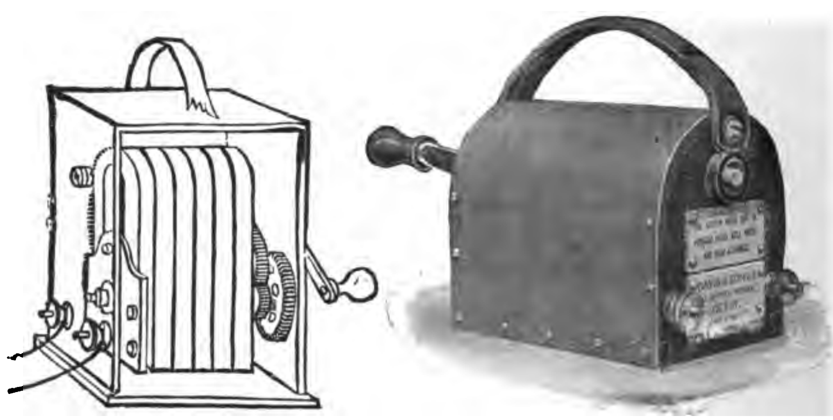
The electric generator, primary or secondary battery, should invariably be tested daily.

Magneto-Exploders.

High tension and low tension exploders, Fig. 61, are capable of firing from 1 to 20 Abel's fuses in series through 100 yards of suitable cable.

Cautions.—When testing low tension fuses it is desirable to place the detonator in an iron pipe or box to catch the fragments should the use be accidentally fired.

Fig. 61.



Never connect the cable to an exploder until everything is ready, everybody in safety, and it is intended to fire immediately.

Never press the button of a magneto-exploder until good speed is attained, and continue turning until the shot is fired.

Keep good electric connections by well scraping the wires before jointing.

Procure an exploder well above its work, for fuses vary in resistance ; leakage may occur in the leading wires, and extra resistance may be caused by loose or dirty joints.

Those who have carefully studied and have had experience in electric blasting are most earnest in praise of the method and its economical value.

A very little thought will make apparent the greater effect which can be produced by firing *simultaneously* a number of blasts instead of firing them singly, while a little experience will teach that even in firing single blasts by this apparatus much can be gained. One advantage gained in firing single holes is that in case of miss-fire, which can rarely happen by this method, no time is lost in waiting, as in the case of firing by safety fuse there would be, before approaching the work. There is no "hanging" fire.

Another advantage is that the explosion of the electrical fuse in the centre of the charge throws the fire through the whole body of the powder, igniting it all at once, and by *detonation* giving the same charge much greater explosive effect.

"Pull Up" Blasting Machines.

Capacity, 10 to 75 holes.

In this blasting machine, between the field pieces there is fitted to revolve an armature wound to a very high resistance. The rapid rotation of the armature by pulling up the operating bar generates an electric current of high electro motive power, which at the moment of its maximum intensity, is sent out to the outside circuit, containing the exploders, the firing of which is instantly accomplished.

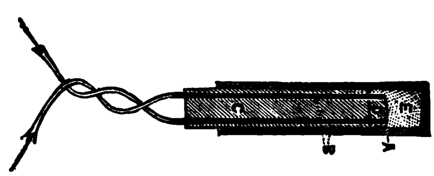
Some persons, in using the machine, move the rack-bar several times up and down, with a churning motion, before giving the final stroke. There is no reason in this practice, and it is likely to damage

the machine or make it entirely useless. In forcing down the rack-bar, a certain amount of heat is communicated to parts of the apparatus; with but one stroke this is not sufficient to harm, and is almost immediately dissipated, but by several strokes in quick succession heat may be generated faster than it can be dispersed, and thus there may be so much accumulated in certain parts as to destroy them.

Since the efficiency of a blasting machine may have become impaired in some way and remain unknown to the operator, it is very desirable that the machine be tried from time to time with the testing lamp.

It should be clearly understood, for it is really very important, that the blasting machine should have careful handling. Where complaints have been made of unsuccessful blasts, and the cause alleged as due to the dynamite or to the electrical exploders, it has been found to be invariably true that the real cause was the attempt to fire the blast with an apparatus which was out of order, worn out, or too small to explode the number of holes required.

Fig. 62. Electric Fuses or Exploders.



The wires are of the purest copper, of a size of about 20 gauge, well insulated with the best of cotton, wound double; the second winding the reverse of the first, then insulated with a waterproof insulation. The copper shell, or cap, contains a very strong and powerful explosive, about double the strength of the best blasting cap, as the stronger the cap, the better results will be obtained from the powder, especially in cold weather. Fuses made with weak caps may explode the powder, but will do so imperfectly, as a weak detonation will create only a slow burning of the explosive; consequently, a great part of the strength is lost.

Caps.

Detonating Caps are thin copper shells, less than one-quarter of an inch in diameter, and from one to one and a half-inches in length, and are used—in connection with safety fuse—in exploding dynamite, &c. These caps, or copper shells, are partly filled with a very powerful and highly sensitive fulminating powder, readily exploded by heat, fire, or a blow ; and rendered worthless by water or damp.

Detonating Caps are made in many strengths, from single force, containing from three to four grains in weight, to sextuple force, containing 17 to 18 grains of fulminating powder, with the intermediate grades of double, triple, quadruple and quintuple force.

Single and double force caps are of little value in exploding dynamite, as the detonation caused by so low a strength is insufficient to thoroughly explode it, and much of its force is lost. Triple force caps, of the best quality, do reliable work in a mild temperature ; but when below 40 degrees Fahrenheit, a stronger cap is preferable.

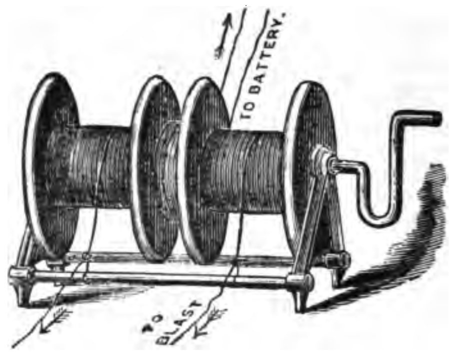
Connecting Wire.

This wire is used for the purpose of connecting together the fuse wires in the charge holes, when holes are far apart. It is also used to some extent for splicing out the shorter fuses in very deep hole work, the joints being carefully covered with the insulating tape. It can be picked up after the blast, and used until the insulation becomes injured, when it should be replaced.

Leading Wire.

Enough leading wire is needed with each machine to make two leaders of sufficient length to reach from the blast to a safe distance for the person to stand who shall operate the machine. Five hundred feet is the quantity usually sold, but in some cases a thousand feet are used. Cotton-covered wire is generally used, but gutta-percha covered wire can also be used.

Fig. 63. The Leading Wire Reel.

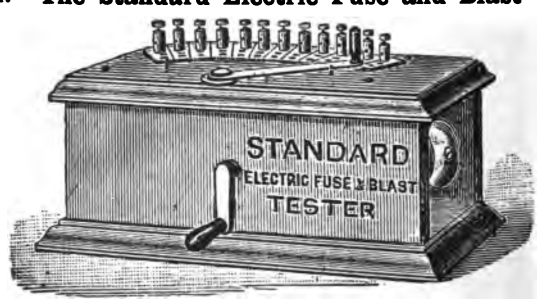


In electric blasting, leading wire forms a very important part, and great care should be taken to have it in good condition and in a convenient form to use. This reel is a simple and practical device to keep the leading wire on ; it is strong and durable, and handy to carry about ; it is the only reel made whereby there can be a continuous wire from the battery to the blast—both wires are separated on the reel, and can be run off in any required length.

Joint Insulation Tape.

This is a most useful and convenient article for covering bare wire joints in blasting, either on dry ground or under water. It is made of "okonite," a superior insulating compound. It forms a perfect and thoroughly waterproof joint, and can be applied instantly.

Fig. 64. The Standard Electric Fuse and Blast Tester.

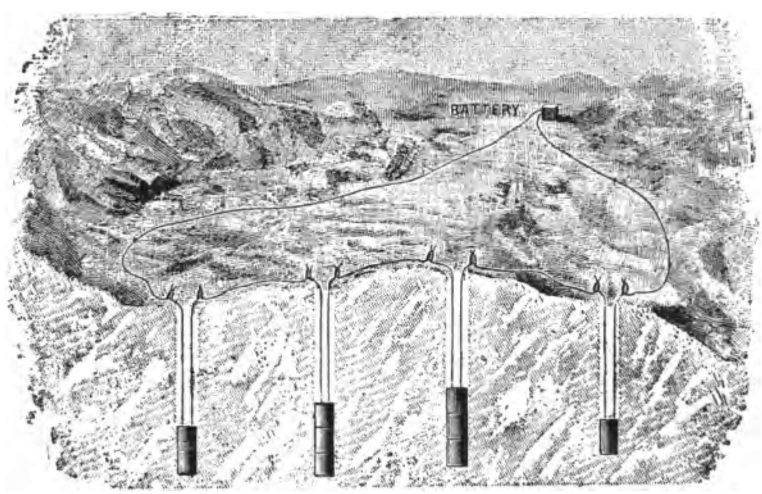


This machine is intended to test electric fuses or exploders before placing them in the charge holes to blast, to make sure that they are all

right and perfect, so as to avoid the expense, trouble and danger of a miss-fire or an unexploded hole. To make doubly sure, with the same machine the entire charge can be tested before putting the leading wire to the battery. If the blast fails after such testing, the trouble must be with the battery or powder. All blasters know the trouble and danger caused by a bad fuse in the charge ; it necessitates the drawing of the charge hole or redrilling another hole, and many accidents and deaths have occurred in performing these dangerous operations. All these dangers can be avoided by the use of the Standard Electric Fuse and Blast Tester.

Fig. 65. Rock Blasting by Electricity.

Showing Holes Connected in Series.



The above cut represents clearly the manner of connecting in series holes for firing by electricity. The electric wire fuse should be about same length as the hole is deep ; better to have the wire a little longer, that it may project above the surface of the hole after it is tamped, for the purpose of connecting it to the wire of the next hole.

Care should be taken, when tamping the holes, not to injure or cut the insulation on the wire, as bare portions of the wires or bare joints should never be allowed to touch the ground ; particularly so if the

ground is wet. After the holes are tamped and made ready to connect for firing, separate the ends of the two wires in the first hole, leaving the outside wire for connecting with the leading or battery wire; then join the inside wire of the first fuse to the nearest wire of the second fuse; then the other wire of the second fuse to one of the wires of the third fuse, and so on until all fuse wires are connected. Then take the outside fuse wires of the two outside or end holes, and join them to the leading wire which goes to the binding posts of the battery, and fasten there by means of a thumb-screw.

If the holes are far apart use connecting wire for joining fuse wires together. The connecting wire should be of the same diameter or size as the fuse wire. The leading wire should be at least twice as thick. Special care must be taken, when making joints for connecting wires together, to have the ends clean and bright, and free from dirt or grease

Batteries should be at a safe distance from the blast, usually about 300 to 500 feet. All workmen should be at a safe distance before operating the battery to fire the charge. An important matter which is seldom thought of by blasters is to examine the leading wire, to see that there are no cracks or breaks in it. Even new lengths of leading wire may be defective. It has been found so in long lengths, where the ends are held together or joined only by a heavy cotton braiding, which prevented the current from passing.

Lightning Conductors.

Collieries.—Undoubted evidence exists of the explosion of fire-damp in collieries through sparks from atmospheric electricity being led into the mines by the wire ropes of the shaft and iron rails of the galleries, hence the head gear of all shafts should be protected by proper lightning conductors.

1.—Form for upper terminals :—A straight copper rod, ¾ inch diameter, with solid copper points screwed to the rod and nickel-plated.

2.—Attachment to building :—The conductor should be fixed close to building *without* insulators, and brought into close contact with the spouting and all metal work, and closely attached to the chimney and walls by means of copper clips and nails driven into the masonry.

Regarding insulators. If there be anything in insulators they are a disadvantage, for if the building be struck in any other part than the conductor, the discharge cannot easily find its way to the conductor. The current will take the least line of resistance; therefore it is reasonable to assume that the building is more certain to escape the disruptive force of lightning when the conductor is in closest proximity to the building.

3.—Ground connection :—Should a good permanent drain or water main be near, the conductor should be brought to it, and bound round and firmly fixed or terminated by a copper plate, 3ft. by 2ft. by $\frac{1}{16}$ in., to which the conductor should be rivetted and soldered.

If there be an open drain or brook, the conductor should be brought under it at a *sufficient* depth that if the stream be dry at any time, there will be sufficient moisture to carry away the charge without disruption. Should there be neither drain pipes nor brook sufficiently near, the conductor should be taken from 12 to 20 feet below the surface, where it is certain to be always damp, even in seasons of the greatest drought.

In no case should the earth connection be led into a closed tank or well.

4.—Supposed area protected :—It is impossible to determine exactly the area the conductor protects. It is erroneously supposed that the rod will protect buildings within its radius; experience will not bear out this axiom. Many instances may be related of buidings struck much within the radius of well protected churches or chimneys.

The protection a conductor affords depends to a great extent on the relative position of the electric discharge, and the objects that it may meet in its course. As a general rule, a high spire of a church, with a proper conductor, may be considered to protect the remainder of the edifice; but a low straggling building should have several conductors *outside* the highest points.

Messrs. J. DAVIS AND SON have recently published an important statement, showing the necessity of periodically testing and repairing lightning conductors. Messrs. Davis point out that it is a popular and dangerous mistake to suppose that a lightning conductor once fixed always remains effective and requires no further attention. Not only is the conductor subject to corrosion, but it is liable in many other ways to get out of order, and may become "worse than useless, and in itself an element of danger." The condition of a conductor can, hov-

ever, always be tested by means of a battery and galvanometer, and, as the test is easy and inexpensive, it ought to be employed by all who are responsible for the safety of houses or public buildings that are supposed to be protected by lightning conductors. An investigation at the Glasgow General Assembly Hall proved that the old conductor, instead of guarding the building was really endangering it, and there is no doubt that hundreds of these appliances are at the present moment in a similar state.

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